NEW ENGLAND WATER WORKS ASSOCIATION.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

WATER-WORKS STATISTICS FOR THE YEAR 1906, IN FORM ADOPTED BY THE NEW ENGLAND WATER WORKS ASSOCIATION.

COMPILED BY CHARLES W. SHERMAN, EDITOR, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

The tables presented herewith contain statistics of forty-three water works, as summarized in their annual reports. These are all municipally owned water works. There are other water works which summarize their statistics, but the compiler has not succeeded in obtaining their reports for the year 1906.

The report of the Committee on Uniform Statistics, containing the form as endorsed for use in the 1901 reports, is printed on page 51 of Vol. XV of the JOURNAL (March, 1902). The page for Financial Statistics was changed by vote of the Association in September, 1902, as reported in the December, 1902, JOURNAL (Vol. XVI, p. 263). Blank forms for use in preparing summaries are printed by the Association, and will be furnished on request.

Previous compilations of statistics may be found in the JOURNAL, as follows:

Statistics for	Reference to Journal.
1886	Vol. I, No. 4, p. 29
1887	Vol. II, No. 4, p. 28
1888 to 1892 inclusive	Vol. VII, p. 225
1893	Vol. IX, p. 127
1894	Vol. X, p. 131
1895–96	Vol. XII, p. 273
1897–99	Vol. XV, p. 65

Statistics for	Reference to Journal.
1900	Vol. XV, p. 367
1901	Vol. XVI, p. 223
1902	Vol. XVII, p. 235
1903	Vol. XVIII, p. 277
1904	Vol. XIX, p. 241

In the various tabulations, statistics are given for the following places and years:

Place.	Year.
Albany, N. Y.	1900
Andover, Mass.	1900
Arlington, Mass.	1900, 1904, 1906
Atlantic City, N. J.	1898, 1900–04
Attleboro, Mass.	1894–1904, 1906
Bay City, Mich.	1886–87, 1893–96, 1900–04
Belmont, Mass.	1902–04, 1906
Beverly, Mass.	1903, 1906
Billerica, Mass.	1899–1904, 1906
Boston, Mass.	1886–94, 1897, 1900, 1903
Bridgeport, Conn.	1904
Brockton, Mass.	1893–1904, 1906
Burlington, Vt.	1886–1904, 1906
Cambridge, Mass.	1900–04, 1906
Chelsea, Mass.	1900–04, 1906
Cleveland, Ohio	1902–04, 1906
Concord, N. H.	1895, 1898, 1900–04
Dover, N. H.	1900
Erie, Pa.	1900
Essex Junction, Vt.	1900
Fall River, Mass.	1886–95, 1897–1904, 1906
Fitchburg, Mass.	1886–92, 1894–1904, 1906
Freeport, Me.	1901
Geneva, N. Y.	1900
Gloucester, Mass.	1906
Harrisburg, Pa.	1906
Haverhill, Mass.	1900, 1904, 1906
Holyoke, Mass.	1886–92, 1897–98, 1900–04, 1906
Hull, England	1900
Ipswich, Mass.	1900
Keene, N. H.	1899–1900, 1903–04
Lawrence, Mass.	1902–04
Leicester, Mass.	1900
Leominster, Mass.	1900
Lewiston, Me.	1900

Place.	Year.
Lowell, Mass.	1886, 1897–1904, 1906
Lynn, Mass.	1888–98, 1900–04, 1906
Madison, Wis.	1900, 1902–04, 1906
Manchester, N. H.	1900
Marlborough, Mass.	1900, 1903–04, 1906
Maynard, Mass.	1901–03
Metropolitan Water Works, Mass.	1900–04, 1906
Middleboro, Mass.	1895–1904, 1906
Middletown, Conn.	1902
Minneapolis, Minn.	1900–04, 1906
Nantucket, Mass.	1900
Nashua, N. H.	1900, 1904
New Bedford, Mass.	1886–1904, 1906
New London, Conn.	1886–1904, 1906
Newton, Mass.	1888–1904, 1906
Norwich, Conn.	1901
Oberlin, Ohio	1893–1904, 1906
Plymouth, Mass.	1886–1904, 1906
Providence, R. I.	1897–1904, 1906
Quincy, Mass.	1893, 1900–01
Reading, Mass.	1893, 1895–1904, 1906
Reading, Pa.	1901–04, 1906
Rochester, N. Y.	1903
St. John, N. B.	1902–03
Salem, Mass.	1900
Sandusky, Ohio	1886
Schenectady, N. Y.	1886, 1900–01
Somerville, Mass.	1900–04, 1906
Springfield, Mass.	1886–1904, 1906
Taunton, Mass.	1886–1904, 1906
Toronto, Canada	1893
Trenton, N. J.	1886–87
Troy, N. Y.	1886, 1888–93, 1897–99
Waltham, Mass.	1886–1904, 1906
Ware, Mass.	1886, 1888–92, 1900–04, 1906
Watertown, Mass.	1900
Wellesley, Mass.	1888–93, 1898–1904, 1906
Westerly, R. I.	1902–04, 1906
Whitman, Mass.	1897–1904, 1906
Wilmington, Del.	1900
Winchendon, Mass.	1900–04, 1906
Woburn, Mass.	1900–04
Woonsocket, R. I.	1886–1900, 1902–04, 1906
Worcester, Mass.	1900, 1906
Yonkers, N. Y.	1893–96, 1900–04, 1906

1906. — TABLE 1. — GENERAL AND PUMPING STATISTICS.

Number.	Name of city or town.	Date of construction of works.	By whom owned.	Source of supply.	Mode of supply	1	2. — Description of fuel used.				
						Builders of pumping machinery.	*a* Kind.	*b* Brand of coal.	*c* Av. price per gross ton.	*d* Per cent. of ash.	*e* Wood. Price per cord.
1	Arlington, Mass.	1872 1894	Town.	Metropolitan W.W.	.....	.....	.....	.....	....	..	....
2	Attleboro, Mass.	1873	Town.	Well.	Pumping.	Deane, Barr.	Bituminous.	Georges Cr.	....	..	....
3	Belmont, Mass.	1887	Town.	Metropolitan W.W.	.....	.....	.....	.....	....	..	....
4	Beverly, Mass.	1869 1886	City.	Wenham Lake, Longham Res.	Pumping.	Holly.	Bituminous.	Georges Cr.	$3 74	11.2	....
5	Billerica, Mass.	1898	Town.	Driven Wells.	Pumping.	Barr.	Bituminous.	New River.	4 85	..	....
6	Brockton, Mass.	1880 1902	City.	Silver Lake.	Pumping.	Barr.	Bituminous.	New River.	4 90	10.6	....
7	Burlington, Vt.	1867	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.	.....	3 50	..	....
8	Cambridge, Mass.	1855	City.	Hobbs Brook, Stony Brook, Fresh Pond.	Pumping.	Groshon, Worthington, Blake.	Bituminous.	Quemahoning Orenda.	3 70 4 00 4 30	.. .. ..	....
9	Chelsea, Mass.	1867	City.	Metropolitan W.W.	.....	.....	.....	.....	....	..	....
10	Cleveland, Ohio.	1856	City.	Lake Erie.	Pumping.	Worthington, Knowles, Allis, Kilby, Holly.	Bituminous.	Pittsburg Slack.	1 85	..	....
11	Fall River, Mass.	1874	City.	N. Watuppa Lake.	Pumping.	Worthington, Davidson.	Bituminous.	Cumberland, Georges Cr.	....	..	....
12	Fitchburg, Mass.	1873	City.	Storage Reservoirs.	Gravity.	.....	.....	.....	....	..	....
13	Gloucester, Mass.	1884	City.	Reservoirs.	Pumping.	Knowles, Barr.	Bituminous.	Georges Cr.	5 00	8.5	....
14	Harrisburg, Pa.	1843	City.	Susquehanna R. (filtered).	Pumping.	Barr, Harrisburg.	Anthracite.	Pea.	1 25	17	....

14	Harrisburg, Pa.	1843	City.	Susquehanna R. (filtered).	Pumping.	Barr, Harrisburg.					
15	Haverhill, Mass.	..	City.	Ponds.	Gravity and Pumping.	Worthington, Deane, Barr.	Bituminous.	Cumberland, Carbon.	$5 16	10	....
16	Holyoke, Mass.	1873	City.	Lakes and Res'v's.	Gravity.	.....	.....	.....	....	..	....
17	Lowell, Mass.	1870	City.	Driven Wells.	Pumping.	Morris, Worthington, Deane, Knowles.	Bituminous.	Pocahontas, Argyle, New River.	5 02	..	....
18	Lynn, Mass.	1871	City.	Ponds and River.	Pumping.	Leavitt, Loretz.	Bituminous.	Georges Cr.	....	13.1	....
19	Madison, Wis.	1882	City.	Artesian Wells.	Pumping.	Allis-Chalmers, Knowles.	Anthracite.	Pea.	4 52	..	....
20	Marlboro, Mass.	1883	City.	Lake and Res.	Pumping.	Blake, Worthington, Barr.	Bituminous.	Various.	5 05	..	....
21	Metropolitan Water Works, Mass.	1848 1872 1895	State of Massachusetts.	L. Cochituate, Sudbury River, Nashua River.	Pumping, 73%. Gravity, 27%.	*Chestnut Hill* Holly, Quint'd Allis.	*Hill High* Bituminous.	*Service Stat'n* Quemahoning, Orenda, Georges Cr., Cumberland, Peerless, Miller V., Vulcan, Carbon.	4 09 to 4 79	11.9	....
							Anthracite.	Buckwheat, Screenings.	2 93 2 52		
						Chestnut Hill Holly.	*Low Service* Bituminous.	*Station.* Quemahoning, Orenda, Carbon.	4 00 to 4 42	13.4	....
							Anthracite.	Buckwheat, Screenings.	2 84 2 52		
						Spot Blake, Holly.	*Pond* Bituminous.	*Station.* Georges Cr., Cumberland.	4 35 to 4 38	12.9	....
							Anthracite.	Screenings.	2 24		
22	Middleboro, Mass.	1885	Fire Dist.	Well.	Pumping.	Deane.	Bituminous.	Pocahontas.	4 58	..	....
23	Minneapolis, Minn.	1868	City.	Mississippi River.	Pumping.	Worthington, Holly.	Sawdust and edgings. Coal.	.....	3 27	..	$1 35

1906. — TABLE 1, *Continued.* — GENERAL AND PUMPING STATISTICS.

Number.	Name of city or town.	Date of construction of works.	By whom owned.	Source of supply.	Mode of supply.	1	2. — Description of fuel used.				
						Builders of pumping machinery.	*a* Kind.	*b* Brand of coal.	*c* Av. price per gross ton.	*d* Per cent. of ash.	*e* Wood. Price per cord.
24	New Bedford, Mass.	1866	City.	Ponds.	Pumping.	Dickson.	Bituminous.	Georges Cr. Pocahontas.	$4 61 4 64	7	....
25	New London, Conn.	1872	City.	Lake and Res.	Gravity and Pumping.	.....	.....	.....	....	..	....
26	Newton, Mass.	1876	City.	Collecting Gallery.	Pumping.	Barr, Worthington.	Bituminous. Anthracite.	Georges Cr., New River. Screenings.	4 20	14	$6 00
27	Oberlin, Ohio.	1887	Village.	E. Br., Vermillion R.	Pumping.	Deane.	Bituminous.	Pocahontas.	4 10	..	....
28	Plymouth, Mass.	1855	Town.	Ponds.	Gravity and Pumping.	Barr, Worthington.	Bituminous.	Various.	5 00	..	....
29	Providence, R. I.	1870	City.	Pawtuxet River. (filtered.)	Pumping.	Allis-Chalmers.	Bituminous.	New River.	4 17	8.9	4 50
						Worthington.	Bituminous.	New River.	4 17	7.3	4 50
						Corliss.	Bituminous.	New River.	4 17	11.4	4 50
						Holly.	Anthracite.	Buckwheat.	3 23	20.0	3 50
						Nagle.	Anthracite.	Buckwheat.	3 23	16.2	3 50
30	Reading, Mass.	1891	Town.	Filter Gallery.	Pumping.	Blake.	Bituminous.	Carbon Fge.	5 70	..	....
31	Reading, Pa.	1819	City.	Creeks and Springs.	Gravity and Pumping.	Worthington, Allis-Chalmers.	Bituminous.	.....	2 63	9.4	3 50
32	Somerville, Mass.	1868	City.	Metropolitan W.W.	.....	.....	.....	.....	....	..	....
33	Springfield, Mass.	1864	City.	Reservoirs.	Gravity.	.....	.....	.....	....	..	....
34	Taunton, Mass.	1876	City.	Ponds.	Pumping.	Holly, Allis.	Bituminous.	Georges Cr. Cumberland.	5 15 4 50 & 4 65	..	....

35	Waltham, Mass.	1872	City.	Filter Basin.	Pumping.	Barr, Worthington.	Bituminous. Anthracite.	Pocahontas, Screenings.	$5	25	12.5	....
36	Ware, Mass.	1886	Town.	Wells.	Pumping.	Deane, Warren.	Bituminous.	.....	5	00	..	$4 50
37	Wellesley, Mass.	1884	Town.	Wells.	Pumping.	Blake.	Bituminous.	Georges Cr., Cumberland.	4	63	9.0	3 50
38	Westerly, R. I.	1886	Town.	Driven Wells.	Pumping.	Worthington.	Bituminous.	Georges Cr.	4	84	..	6 00
39	Whitman, Mass.	1883	Town.	Brockton W. W.[1]	Pumping.	.....	.....	.....	....		..	....
40	Winchendon, Mass.	1896	Town.	Well.	Pumping.	Blake.	Bituminous.	.....	5	02	14.9	....
41	Woonsocket, R. I.	1884	City.	Crook Fall Brook.	Pumping.	Worthington, Deane, Builders I. Fdy.	Bituminous.	Pocahontas.	5	28	8.3	3 00
42	Worcester, Mass.	1845	City.	Reservoirs.	Gravity.	.....	.....	.....	....		..	....
43	Yonkers, N. Y.	1876	City.	Brooks, Rivers, and Wells.	Pumping.	Wright, Worthington, Wood.	Bituminous.	Georges Cr.	4	10	10.8	12 00

[1] See Brockton.

1906. — TABLE 1, *Concluded.* — PUMPING STATISTICS.

Number.	3 Coal consumed for the year. (Lbs.)	4 Lbs. of wood ÷ 3 = equivalent coal.	4a Amount of other fuel used.	5 Total equivalent coal consumed for the year. (Lbs.) (3) + (4).	6 Total pumpage for the year in gallons.	7 Average static head against which pumps work. (Feet.)	8 Averaged dynamic head against which pumps work. (Feet.)	9 Number of gallons pumped per lb. of equivalent coal.	10 Duty in foot-pounds per 100 pounds of coal. No deductions.	11 Cost per million gallons pumped into reservoir, figured on pumping station expenses.	12 Cost per million gallons raised 1 foot high, figured on pumping station expenses.
2	609 321	.....	....	.....	223 793 920	...	188 225	367	72 955 200	.....	.....
4	1 040 557	.....	....	.....	519 152 436[1]	126	146	496	60 789 667	$17 56	$0 12
5	308 311	.....	....	.....	30 763 788[1]	290	318	100	26 419 693	65 84	0 21
6	1 772 279	.....	....	1 772 279	674 914 949[1]	202	288	381	91 469 329	11 64	0 04
7	2 864 600	.....	....	.....	368 257 775[1]	289	316	129	33 237 044	23 02	0 07
8	4 316 255	500	....	4 316 755	3 386 180 600[1]	158	194	784	127 205 058	5 86	0 03
10	46 722 200[a]	.....	....	46 722 200[a]	21 552 886 258[1a]	171[a]	202[a]	461[a]	77 870 010[a]	4 21	0 02
11	2 139T	.....	....	.....	1 634 300 539	...	185	341	.....	10 52	.....
13	893 659	.....	....	893 659	454 843 889[1]	117	140	509	59 427 110	12 24	0 09
14	11 994 858	.....	....	.....	3 803 869 700[1]	200	235	321	65 132 042	5 33	0 02
15	1 955 678	.....	....	1 955 678	1 060 562 257[2]	190	203	730 242	91 812 808	12 01	0 06
17	7 904 865	2 400	....	7 907 265	1 855 043 406	156	164	235	62 941 506	20 60	0 13
19	1 835 100	.....	....	.....	522 648 000[1]	201	231	...	.....	.....	.....
20	622 900	.....	....	.....	202 340 250[2]	172	174	318	47 138 879	12 99	0 07
*21*a*	3 014 777	.....	....	.....	1 905 110 000[2]	...	121	632	65 670 000	6 64	0 06
b	518 933	.....	....	.....	514 220 000[2]	...	128	991	114 550 000	3 50	0 03
c	8 518 537	.....	....	.....	10 310 810 000[2]	...	132	1 210	136 740 000	2 91	0 02
d	7 955 358	.....	....	.....	18 938 590 000[2]	...	51	2 381	104 520 000	1 69	0 03
e	2 533 049	.....	....	.....	3 031 770 000[2]	...	128	1 197	131 600 000	4 03	0 03
22	638 510	.....	....	638 510	112 318 000[1]	182	204	176	29 928 012	.....	.....
23	9 811 025	.....	....	.....	6 426 708 815	218	237	...	71 300 000 to 89 400 000	.....	.....
24	2 879 165	.....	....	2 879 165	2 493 186 540[2]	168	185	865	133 309 911	6 31	0 03
26	2 092 000	4 000	....	2 096 000	811 927 159[1]	235	262	387	84 643 400	11 65	0 04
27	555 900	.....	....	555 900	71 800 000[2]	80	84	111	9 050 000	34 68	0 40
28	442 140	.....	....	.....	214 305 800	65	83	475	32 000 000	16 46	0 20
29	5 346 050	333	....	5 346 383	5 169 354 626[2]	171	180	967	144 947 660	L. S.	L. S.
	682 800	.....	....	682 800	368 533 660[2]	170	174	540	78 545 307	5 40	0 03
	120 600	.....	....	120 600	81 354 806[2]	172	181	675	101 673 593	H. S.	H. S.
	1 524 518	911	....	1 525 429	614 370 545[2]	121	131	403	43 911 603	15 70	0 11
	26 766	70	....	26 836	10 665 717[2]	120	127	397	42 112 692		

30	463 076	.....	....	.....	53 551 083[2]	219	240	116	23 125 329	$47 26	$0 20
31	5 411 600	1 800	0	5 413 400	2 135 257 590[1]	213	292	394	96 089 905	6 12	0 02
34	489 900	.....	....	.....	624 296 554	...	...	...	.....	11 60	.....
	1 377 300				698 149 375						
35	1 348 870	.....	....	.....	705 360 048[1]	164	180	530	90 140 773	10 25	0 06
36	650 314	700	....	651 014	128 538 540[1]	221	244	197	40 178 980	28 50	0 12
37	616 472	300	....	616 772	99 481 861	260	280	161	37 646 000	29 63	1 05
38	1 504 600	500	0	1 505 100	264 982 500[2]	195	210	176	30 834 200	23 33	0 11
40	318 992	.....	....	.....	40 305 620	246	289	148	36 349 966	28 33	0 10
41	1 472 850	607	....	1 473 457	446 894 141[2]	238	239	303	60 477 615	15 43	0 06
43	8 700 009	.....	....	8 700 009	2 543 288 786[1]	185	210	358	66 254 081	10 61	0 05
							222	264	46 562 747		

[1] Without allowance for slip.
[2] With allowance for slip.
a. Kirtland Street Station.

* 21*a*. C. H. H. S. Station, engines 1 and 2.
b. C. H. H. S. Station, engine 3.
c. C. H. H. S. Station, engine 4.
d. C. H. L. S. Station, engines 5, 6, and 7.
e. Spot Pond Station, engine 9.

1906. — TABLE 2. — FINANCIAL STATISTICS.

Number.	Name of city or town.	Receipts.						
		Balance brought forward.		Water rates.			Municipal departments.	
		a	b	A	B	C	D	E
		From ordinary receipts.	From extraordinary receipts.	Fixture rates.	Meter rates.	Total from consumers.	For hydrants.	For fountains.
1	Arlington, Mass.	$9 672 88	.....	$24 538 38	$14 438 01	$38 976 39	.....	.....
2	Attleboro, Mass.	.....	$35 945 20	.....	.....	35 373 28	.....	.....
3	Belmont, Mass.	92 36	247 12	.....	14 824 29	.....	.....	.....
4	Beverly, Mass.	353 23	.....	39 284 29	15 922 58	55 206 87	.....	.....
5	Billerica, Mass.	.....	.....	1 100 20	2 692 94	3 793 14	$2 300 00	.....
6	Brockton, Mass.	.....	21 742 44	3 149 17	97 965 34	101 114 51	.....	.....
7	Burlington, Vt.	45 111 42	947 41	6 641 81	38 920 17	45 561 98	620 00	$617 69
8	Cambridge, Mass.	.....	.....	.....	.....	357 280 19	.....	.....
9	Chelsea, Mass.	.....	.....	83 390 24	47 215 17	130 605 41	.....	.....
11	Fall River, Mass.	33 424 25	.....	2 419 69	186 749 92	.....	.....	.....
12	Fitchburg, Mass.	.....	.....	15 326 12	57 685 39	.....	.....	.....
13	Gloucester, Mass.	14 565 43		65 576 50	18 944 86	84 521 36	.....	.....
14	Harrisburg, Pa.	.....	.....	34 340 38	140 544 11	174 884 59	.....	.....
15	Haverhill, Mass.	36 685 84	.....	79 131 64	28 305 31	107 436 95	.....	.....
16	Holyoke, Mass.	3 865 25	.....	86 522 97	31 000 29	117 523 26	.....	.....
17	Lowell, Mass.	31 791 82	.....	28 816 73	150 373 42	179 190 15	.....	.....
18	Lynn, Mass.	.....	1 988 22	113 684 29	130 702 29	244 386 58	.....	.....
19	Madison, Wis.	9 893 04	.....	.....	.....	31 263 33	.....	.....

20	Marlboro, Mass.	$603 80	.....	$10 829 41	$26 553 15	$37 382 56	$6 700 00	.....
22	Middleboro, Mass.	1 007 71	.....	3 407 54	7 454 23	10 861 77	.....	.....
23	Minneapolis, Minn.	.....	.....	53 943 96	200 911 49	254 855 54	.....	.....
24	New Bedford, Mass.	37 316 64	$14 122 75	78 838 23	120 568 09	199 406 32	.....	.....
25	New London, Conn.	79 507 62	.....	.....	.....	66 389 86	12 840 00[1]	$300 00[1]
26	Newton, Mass.	.....	.....	2 157 00	120 325 00	122 482 00	.....	.....
27	Oberlin, Ohio	.....	.....	894 25	10 767 75	11 662 00	.....	.....
28	Plymouth, Mass.	.....	849 42	.....	.....	29 260 19	.....	.....
30	Reading, Mass.	28 19	.....	.....	11 047 52	11 047 52	4 950 00	300 00
31	Reading, Pa.	19 218 46	.....	157 368 79	53 430 52	210 799 31	.....	.....
32	Somerville, Mass.	.....	.....	133 886 92	92 533 42	226 420 34	.....	.....
33	Springfield, Mass.	19 249 10	.....	141 609 52	118 577 47	260 186 99	26 850 00[1]	670 00[1]
34	Taunton, Mass.	.....	3 353 53	.....	.....	71 236 11	.....	.....
35	Waltham, Mass.	5 651 09	60 760 07	59 180 57	15 490 75	74 671 32	.....	.....
36	Ware, Mass.	3 360 39	191 26	.....	9 173 86	10 503 87	.....	171 45
37	Wellesley, Mass.	4 768 82	513 90	240 00	15 832 69	16 072 69	3 500 00[2]	.....
38	Westerly, R. I.	12 061 66	.....	2 787 38	27 611 60	30 398 98	3 208 32	.....
39	Whitman, Mass.	17 80	.....	2 700 25	6 578 71	.....	2 920 00	.....
40	Winchendon, Mass.	917 55	.....	76 40	7 159 89	7 236 29	4 680 00	313 96
41	Woonsocket, R. I.	.....	.....	2 470 70	68 078 54	70 549 24	17 875 00	2 170 64
43	Yonkers, N. Y.	.....	45 899 60	.....	.....	160 198 15	30 990 00	.....

[1] Book account only.

[2] Includes fountains and street watering.

1906. — TABLE 2, *Continued.* — FINANCIAL STATISTICS.

Number	Receipts — *Continued.*								
	Municipal departments — *Continued.*					K	L	M	N
	F For street watering.	G For public buildings.	H For miscellaneous uses.	I General appropriation.	J Total from municipal departments.	From tax levy.	From bond issue.	From other sources.	Total receipts.
1	.....	.....	.....	$7 000 00	.....	.....	$835 41	.....	.....
2	.....	.....	.....	1 000 00	.....	.....	.....	$7 295 43	.....
3	.....	.....	.....	1 000 00	.....	.....	5 500 00	926 37	$22 343 02
5	.....	.....	.....	937 09	.....	.....	.....	57 04 149 32	.....
6	$1 000 00	.....	.....	.....	$1 000 00	.....	45 000 00	60 329 59	229 186 54
7	1 687 12	$207 26	$45 111 42	.....	.....	.....	.....	947 41	.....
8	.....	.....	.....	.....	.....	.....	.....	5 961 77 3 627 24	366 869 20
9	.....	.....	.....	.....	.....	$10 000 00	.....	1 762 79	142 368 20
11	.....	.....	.....	.....	.....	.....	.....	409 02 3 360 93	226 363 81
12	.....	.....	.....	.....	.....	.....	.....	6 574 37	79 585 88
13	.....	.....	.....	7 786 00	7 786 00	.....	30 000 00	2 828 92	139 701 71
14	.....	.....	.....	.....	.....	.....	.....	7 386 44	182 271 08
15	.....	.....	.....	.....	.....	.....	.....	9 450 07	153 572 86
16	.....	.....	.....	.....	.....	.....	.....	5 684 90	127 073 41
17	1 500 00	4 650 40	.....	.....	6 150 40	17 800 00	27 000 00	26 115 39	288 047 76
18	.....	.....	.....	.....	.....	.....	.....	16 009 61	262 384 41
19	.....	.....	.....	.....	.....	10 000 00	.....	4 705 42	55 861 79
20	.....	227 27	5 40	.....	6 992 67	.....	.....	2 623 76	47 602 69

22	.....	.....	.....	.....	$1 500 00	.....	.....	$1 360 93	$14 730 41
23	.....	.....	.....	.....	.....	$78 163 53	.....	?	360 224 92
24	.....	.....	.....	.....	.....	.....	.....	.....	250 845 71
25	$1 500 00[1]	$1 500 00[1]	.....	.....	16 140 00[1]	.....	.....	.....	163 144 99
26	3 000 00	2 681 00	.....	.....	5 681 00	.....	$5 028 47	9 286 00	.....
27	.....	.....	$456 88	.....	456 88	3 076 95	.....	36 995 51 358 10	15 553 93
28	.....	.....	.....	.....	.....	.....	.....	3 563 29	.....
30	500 00	.....	.....	.....	5 750 00	.....	.....	843 01	17 668 72
31	.....	.....	.....	.....	0	.....	.....	14 571 24	244 589 01
32	.....	.....	.....	.....	.....	.....	.....	7 880 11	234 300 45
33	6 627 45[1]	13 509 59[1]	4 503 65[1]	.....	52 160 69[1]	.....	.....	27 442 55	359 039 33
34	.....	808 50	.....	.....	.....	10 000 00	.....	3 619 00	.....
35	.....	.....	1 820 60	.....	1 820 60	.....	40 000 00	1 250 51 3 608 30	186 511 38
36	.....	37 00	365 29	.....	573 74	2 700 00	.....	229 25	.....
37	.....	263 34	.....	.....	3 763 34	.....	5 066 67	1 586 30	32 188 20
38	.....	.....	.....	.....	3 208 32	.....	.....	416 48 2 896 38	48 565 34
39	110 22	.....	.....	$2 500 00	.....	800 00	.....	3 269 31	18 896 28
40	203 10	.....	.....	.....	5 197 60	8 000 00	.....	40 98	21 391 88
41	2 079 36	1 537 58	812 07	39 000 00	63 474 66	.....	.....	3 719 21	137 743 11
43	.....	.....	.....	.....	.....	.....	180 718 50	6 883 89	.....

[1] Book account only.

1906. — TABLE 2, *Continued.* — FINANCIAL STATISTICS.

Number.	Maintenance Expenditures.			DD	EE	FF	Construction Expenditures.				
	AA	BB	CC				GG	HH	II	JJ	KK
	Operation.	Special.	Total maintenance.	Interest on bonds.	Payment of bonds.	Sinking fund.	Extension, of mains.	Extension of services.	Extension of meters.	Special.	Total constr'tion.
1	$4 226 57	$13 663 78[1]	.....	$12 960 00	.....	$13 000 00	$835 41	$1 016 88	$2 887 66	.....	.....
2	.....	.....	$11 578 28	18 295 00	.....	6 500 00	.....	.....	.....	.....	$33 260 62
3	2 134 87	5 668 67[1]	.....	1 370 00	$3 250 00	520 00	2 565 11	1 003 37	941 66	$1 182 57	5 692 71
4	20 430 89	.....	20 430 89	.....	.....	.....	7 360 02	3 076 31	1 022 05	724 81	12 183 19
5	.....	.....	4 011 67	3 600 00	.....	.....	.....	106 85	32 05	73 33	212 23
6	38 115 37	.....	38 115 37	56 547 50	50 000 00	7 866 14	44 483 18	7 019 62	5 659 90	2 641 56	59 804 26
7	22 664 36	.....	.....	8 720 00	60 000 00	14 674 47	279 08	674 93	1 083 56	.....	1 370 52
8	.....	.....	68 851 32	143 827 75	12 500 00	123 247 50	.....	.....	394 77	.....	318 460 76
9	12 387 74	57 687 81[1]	70 075 55	12 000 00	.....	5 410 00	.....	.....	3 636 74	.....	8 655 14
11	.....	.....	47 595 87	67 910 00	.....	.....	17 642 99	.....	.....	23 781 19	.....
13	23 007 55	.....	23 007 55	41 600 00	45 000 00	.....	3 835 66	5 923 51	.....	8 838 00	22 812 78
14	61 474 84	14 405 61	95 880 45	34 552 00	.....	40 632 63	.....	.....	.....	4 215 61	.....
15	25 136 77	.....	25 136 77	39 240 00	5 000 00	18 000 00	5 913 76	5 460 68	682 08	14 571 01	26 627 53
16	42 969 94	4 991 34	7 961 28	13 750 00	.....	32 020 24	9 532 96	.....	2 246 40	16 151 00	27 930 36
17	109 294 73	.....	109 294 73	45 668 00	16 600 00	17 800 00	34 432 72	8 443 95	.....	.....	42 876 67
18	.....	.....	117 389 78	68 740 00	.....	64 000 00	.....	.....	.....	.....	4 972 30
19	.....	.....	20 309 79	.....	.....	5 000 00(?)	.....	.....	.....	.....	23 786 99
20	9 368 25	.....	9 368 25	20 760 00	.....	.....	.....	.....	.....	.....	2 682 96
22	$6 643 49	.....	$6 643 49	$1 700 00	.....	$2 500 00	$3 104 26	$473 65	$190 80	.....	$3 768 71

22	$6 643 49	.....	$6 643 49	$1 700 00	.....	$2 500 00	$3 104 26	$473 65	$190 80	.....	$3 768 71
23	.....	.....	138 729 86	.....	.....	.....	.....	.....	.....	.....	166 992 27
24	40 562 72	.....	40 562 72	68 880 00	$30 000 00	28 000 00	20 218 38	5 698 03	4 066 16	$9 536 44	39 519 01
25	10 276 37	.....	10 276 37	21 915 35	.....	.....	10 354 87	3 456 94	1 084 35	5 939 10	20 835 26
26	25 087 00	.....	.....	66 190 00	.....	.....	17 750 60	11 610 61	3 677 80	8 984 97	42 023 98
27	4 976 52	$797 24	5 773 76	1 100 94	4 000 00	.....	353 14	316 74	1 396 02	2 174 40	4 240 30
28	.....	.....	10 767 52	4 847 36	9 666 66	.....	3 344 09	520 45	.....	9 630 12	13 494 66
30	6 268 83	.....	6 268 83	8 105 00	.....	.....	887 59	1 580 57	656 79	160 61	3 285 56
31	53 679 35	1 438 68	55 118 03	16 132 00	.....	51 500 00	16 068 03	1 675 83	3 327 59	43 450 87	84 522 32
32	27 946 76	97 160 08[1]	.....	3 935 00	16 000 00	.....	8 136 78	4 724 12	6 334 96	.....	19 195 86
33	39 334 72	3 150 01 15 372 81	54 707 53	21 875 00	.....	.....	24 054 14	.....	.....	755 02 61 857 87	85 156 99
34	30 734 89	.....	.....	34 195 00	.....	.....	5 456 31	3 006 93	1 702 83	3 400 00	13 566 07
35	38 043 37	5 000 00	43 043 37	18 910 00	.....	14 000 00	3 464 84	4 875 60	160 00	29 771 80	38 272 24
36	7 436 71	.....	.....	1 065 00	2 700 00	.....	.....	.....	.....	.....	1 878 83
37	7 156 00	.....	.....	11 320 00	.....	.....	6 158 83	946 04	.....	.....	.....
38	10 015 42	.....	10 015 42	13 361 70	.....	7 500 00	1 825 25	1 971 88	1 056 01	550 00	5 403 14
39	2 213 54	4 181 80[2]	6 395 34	4 800 00	.....	2 007 55 2 500 00	.....	.....	.....	.....	3 157 52
40	3 792 94	.....	.....	3 400 00	3 000 00	.....	2 495 90	473 60	409 42	7 104 65	10 483 57
41	16 782 30	.....	.....	.....	.....	.....	.....	.....	.....	.....	24 917 21
43	.....	.....	87 924 07	86 783 33	.....	27 000 00	.....	.....	.....	.....	105 560 68

[1] Metropolitan water-works assessment.

[2] Paid city of Brockton for water and pumping.

1906. — TABLE 2, *Concluded.* — FINANCIAL STATISTICS.

Number.	LL	MM Balance.		N		O	P	Q	R
	Unclassified expenses.	*aa* Ordinary.	*bb* Extraordinary.	Total,	Disposition of balance.	Net cost of works to date.	Bonded debt at date.	Value of sinking fund.	Average rate of interest. Per cent.
1	.....	$9 283 25	.....	.....	.....	$511 771 00	$326 000 00	.....	4
2	.....	.....	$9 980 01	.....	.....	629 781 51	487 000 00	$40 526 70	.....
3	.....	2 031 57	1 428 08	$22 343 02	.....	.....	38 250 00	5 820 02	4
4	$38 720 72	.....	.....	71 334 80	.....	507 737 82	.....	.....	.....
5	.....	—524 40	—62 91	.....	.....	92 490 23	.....	.....	.....
6	4 567 50	.....	12 285 77	229 186 54	Forward.	1 713 251 95	1 485 000 00	523 065 53	3.6
7	.....	.....	.....	.....	.....	491 446 59	188 000 00	14 674 47	4
8	4 710 37	.....	.....	.....	.....	6 342 200 46	3 383 600 00	1 509 749 85	3½–4
9	639 20	.....	6 363 26	.....	City Treasury.	507 580 57	300 000 00	110 824 00	4
11	.....	69 433 76	.....	226 363 81	.....	2 076 499 40	1 550 000 00	530 768 51	3.99
12	45 212 66	34 373 22	.....	79 585 88	City Treasury.	446 043 90	532 000 00	85 956 10	.....
13	6 683 39	482 99	115 00	139 701 71	.....	1 386 358 50	1 143 000 00	.....	3½ and 4
14	3 713 00	27 493 00	.....	182 271 08	General Fund.	1 250 000 00	921 600 00	265 560 00	3½
15	26 464 77[1]	39 568 56	.....	153 572 86	.....	1 432 807 88	976 000 00	295 057 54	4
16	2 822 31	2 589 22	.....	.....	.....	1 296 773 85	350 000 00	86 687 42	.....
17	13 355 81	25 101 61	17 350 94	288 047 76	Forward.	3 054 082 82	1 085 400 00	473 908 75	4
18	5 945 47	.....	1 336 86	262 384 41	Const.	2 966 713 22	1 788 500 00	453 262 36	3½
19	.....	6 765 01	.....	55 861 79	.....	477 011 46	32 500 00	.....	3½ and 4
20	.....	$14 791 48	.....	$47 602 69	.....	$593 170 84	$519 000 00	$223 149 45	4

20	.....	$14 791 48	.....	$47 602 69	.....	$592 170 84	$519 000 00	$233 149 45	4
22	.....	118 21	.....	14 730 41	.....	121 962 80	39 000 00	13 068 11	4
23	.....	.....	.....	.....	.....	.....	1 930 000 00	.....	.....
24	.....	43 883 98	.....	250 845 71	Forward.	3 332 753 27	1 578 000 00	367 538 48	4.28
25	$30 000 00[2]	80 118 01	.....	163 144 99	.....	1 019 340 86	601 000 00	.....	3.6
26	.....	46 172 00	.....	.....	.....	2 232 446 00	1 387 000 00	494 911 00	4
27	146 67	292 26	.....	15 553 93	.....	118 277 77	43 000 00	918 12	3.5
28	.....	.....	—$5 103 30	.....	.....	379 758 21	119 999 82	.....	3½ to 4
29	.....	.....	.....	.....	.....	7 228 867 84	433 000 00	382 080 02	3½
30	.....	9 33	.....	17 668 72	Forward.	.....	201 000 00	0	4
31	5 000 00[3]	32 316 66	.....	244 589 01	Forward.	2 908 028 24	400 000 00	94 844 49	4
32	5 10	66 907 64	.....	234 300 45	City Treasury.	874 698 99	86 000 00	.....	4
33	52 022 52[2]	100 875 96	.....	359 039 33	Sinking Fund.	2 399 480 66	555 000 00	151 255 09	3.81
34	22 201 92	22 199 41[4] 7 556 73	3 406 46	.....	Sinking Fund.	1 347 106 32	838 500 00	326 595 77	3½ and 4
35	.....	1 138 34	71 147 43	186 511 38	.....	671 852 57	543 000 00	258 390 93	3.90
36	.....	4 365 54	112 43	.....	.....	143 643 86	27 900 00	.....	3½ and 4
37	72 57 1 703 94[2]	4 768 82	62 00	32 188 20	.....	348 245 26	287 000 00	145 805 85	4
38	.....	12 285 08	.....	48 565 34	Forward.	375 296 80	353 000 00	67 413 27	3¾
39	.....	35 87	.....	18 896 28	.....	165 674 03	120 000 00	.....	4
40	.....	715 37	.....	21 391 88	.....	142 205 27	82 000 00	.....	4
41	.....	.....	96 043 60	137 743 11	.....	258 304 54	1 032 000 00	154 540 35	3.8
43	.....	.....	29 258 22	.....	.....	2 189 040 07	1 895 000 00	304 378 92	5.33

[1] Depreciation. [2] To city treasury. [3] To park department. [4] Inventory.

1906.— TABLE 3.— STATISTICS OF CONSUMPTION OF WATER.

Number	Name of city or town.	1	2	3	4	5	6	7	8	9	10	11	12
		Estimated population.						Average consumption. (Gallons per day.)				Cost of supplying water. Per million gals.	
		Total at date.	On line of pipe.	Supplied at date.	Total consumption for the year. (Gallons.)	Quantity used through meters. (Gallons.)	Percentage of consumption metered.	Total.	To each inhabitant.	To each consumer.	To each tap.	Figured on total maintenance. (Item CC.)	Figured on total maintenance + int'st on bonds.
1	Arlington, Mass.	10 000	9 800	9 700	292 197 000	69 301 230	24	800 541	80	83	426	...	....
2	Attleboro, Mass.	14 000	13 500	....	223 793 920	.....	..	640 635	43	45	...	...	....
3	Belmont, Mass.	4 550	4 350	4 250	.....	57 395 800	..	272 900	62	..	...	...	....
4	Beverly, Mass.	18 000	18 000	18 000	519 152 436	.....	..	1 420 168	79	79	...	$39 35	....
5	Billerica, Mass.	2 850	1 900	1 600	30 763 788	.....	..	84 284	..	53	...	105 11	$222 13
6	Brockton, Mass.	57 000[1]	55 000[1]	54 400[1]	718 339 756	513 537 935	71	1 957 095	34	36	287	53 06	131 78
7	Burlington, Vt.	20 500	20 100	20 000	368 257 775	203 556 600	55	1 008 925	49	50	247	61 54	85 22
8	Cambridge, Mass.	99 934	99 934	99 934	3 386 180 600	1 252 836 750	37	9 277 207	93	93	615	20 33	64 25
9	Chelsea, Mass.	38 000	38 000	38 000	1 348 310 000	305 451 457	22	3 694 000	98	98	567	51 91	60 88
10	Cleveland, Ohio	480 237	478 000	477 000	21 552 886 258	13 050 513 080	60	59 049 003	123	124	876	20 41	28 51
11	Fall River, Mass.	107 911	....	106 370	1 634 300 539	.....	..	4 477 536	41	42	...	...	....
12	Fitchburg, Mass.	33 300	....	31 000	1 062 000 000[2]	.....	..	2 900 000[2]	..	93[2]	...	...	....
13	Gloucester, Mass.	26 011	26 000	20 000	454 843 889	86 036 444	20	1 246 140	48	62	314	50 58	142 04
14	Harrisburg, Pa.	68 000	67 000	70 000	3 803 869 200	2 504 711 500	66	10 421 560	149	149	751	19 56	29 03
15	Haverhill, Mass.	39 000	37 900	37 400	1 696 899 610[2]	.....	..	4 651 779	119	123	732	14 22	37 94
16	Holyoke, Mass.	51 609	51 309	51 034	2 127 856 000	601 384 500	..	5 829 700	113	114	1 502	...	....
17	Lowell, Mass.	96 380	95 789	95 039	1 855 607 433	909 858 986	49	5 083 856	53	53	434	58 90	83 51
18	Lynn, Mass.	85 300	85 300	85 300	1 873 454 975	850 000 000	40	5 132 753	60	60	359	60 00	94 00
19	Madison, Wis.	25 000	....	23 766	.....	191 394 096	..	.....	57	..	362	...	....
20	Marlboro, Mass.	14 072	13 700	13 300	202 340 250	90 924 700	45	554 120	39	42	242	46 29	148 89
21	Met. W.W., Mass.	913 710	....	....	43 369 310 000	.....	..	118 820 000	130	..	...	...	....
22	Middleboro, Mass., Fire Dist.,	4 700	4 400	4 100	112 318 000	50 721 789	45	307 720	73	79	339	...	....
23	Minneapolis, Minn.	275 000	220 000	209 000	6 426 708 815	2 511 393 000	..	17 607 421	64	..	...	...	....
24	New Bedford, Mass.	83 000	77 000	76 000	2 524 786 872	807 861 000	32	6 916 880	83	91	643	16 07	43 35
25	New London, Conn.	22 000	20 800	20 000	892 903 000	.....	..	2 446 300	111	122	632	11 53	36 05
26	Newton, Mass.	38 000	37 600	37 500	811 365 333	514 000 000	63	2 222 919	59	59	290	...	....
27	Oberlin, Ohio	5 000	4 200	3 200	64 000 000	35 000 000	55	176 000	35	55	191	90 20	109 70
29	Providence, R. I.	219 800	....	219 800	5 491 558 313	.....	60[2]	15 045 365	68	..	600	...	....
30	Reading, Mass.	5 725	5 625	5 125	53 551 083	.....	..	146 715	26	29	118	117 93	270 40
31	Reading, Pa.	93 620	93 370	93 530	4 349 047 530	1 404 947 863	32	11 915 199	127	127	576	12 67	16 38
32	Somerville, Mass.	71 000	71 000	71 000	2 248 741 000	.....	..	6 301 000	89	89	...	...	....
33	Springfield, Mass.	80 230	78 000	77 500	3 832 500 000[2]	778 281 426	20	10 500 000[2]	131	135	939	$14 27	$19 98

33	Springfield, Mass. . .	80 230	78 000	77 500	3 832 500 000[2]	778 281 426	20	10 500 000[2]	131	135	939	$14 27	$19 98
34	Taunton, Mass. . . .	30 967	28 500	28 000	698 149 375	287 297 278	41	1 912 738	62	68	386	44 02	93 00
35	Waltham, Mass. . .	27 350	27 200	26 950	705 360 048	76 121 745	11	1 929 726	71	71	533	53 95	94 96
36	Ware, Mass.	8 594	8 305	8 181	128 538 540	84 121 223	65	352 160	42	43	426	66 14	....
37	Wellesley, Mass. . .	6 315	6 070	5 030	99 481 861	61 061 440	61	272 553	43	54	268	...	....
38	Westerly, R. I. . . .	13 500	12 000	11 000	265 092 500	.....	..	723 540	60	66	445	37 77	88 18
39	Whitman, Mass. . .	7 223	....	....	51 412 500	.....	..	.....	..	..	...	...	...
40	Winchendon, Mass. .	6 229	3 700	2 976	40 305 620	19 641 157	49	110 429	18	37	168	94 12	178 48
41	Woonsocket, R. I. .	36 957	37 457	36 957	446 420 731	326 048 066	72	1 223 070	33	33	419	37 59	....
42	Worcester, Mass. . .	138 891	136 582	136 582	3 363 756 000	2 082 903 499	61	9 217 384	66	69	373	26 95	70 09
43	Yonkers, N. Y. . . .	68 000	67 000	67 000	2 543 288 786	.....	51	6 967 914	82	..	1 050	...	....

[1] Including Whitman.

[2] Estimated.

1906. — TABLE 4. — STATISTICS RELATING TO DISTRIBUTION SYSTEM. — MAIN PIPES.

Number.	Name of city or town.	1 Kind of pipe.	2 Sizes of pipes. (Inches.)	3 Length extended during the year. (Feet.)	4 Length discontinued during the year. (Feet.)	5 Total length in use. (Miles.)	6 Cost of repairs. (Per mile.)	7 Number of leaks. (Per mile.)	8 Length of pipe less than 4 ins. diam. (Miles.)	9 Hydrants. Number added.	10 Hydrants. Total in use.	11 Gates. Number added.	12 Gates. Total in use.	13 Gates. Number smaller than 4-inch.	14 Gates. Number of blow-off gates.	15 Range of pressure on mains. (Pounds.)
1	Arlington, Mass.	C. I., Cem. L.	4–12	757	....	35 7	$4 47	..	..	...	364	3	302	...	...	50 & 90
2	Attleboro, Mass.	C. I., W. I., Cem. L.	1–24	.....	....	51 2	....	..	..	11	380	...	....	...	...	85–100
3	Belmont, Mass.	C. I.	2–12	2 247	0	21 0	....	0	0 5	3	163	7	264	25	12	15–100
4	Beverly, Mass.	C. I., Cem. L., Galv.	1–24	22 197	12 256	70 1	26 99	1 5	..	24	364	21	655	...	...	72
5	Billerica, Mass.	C. I.	6–12	.....	....	9 7	....	0 1	..	...	103	...	84	...	4	54–120
6	Brockton, Mass.	C. I., Cem. L.	6–30	17 415	0	100 7	2 09	43	4 5	38	877	83	1 197	72	44	47–56
7	Burlington, Vt.	Cem. L., C. I., W. I.	4–30	240	0	40	....	..	4 8	...	218	...	679	70	14	70–85
8	Cambridge, Mass.	C. I.	2–40	7 443	1 357	128 1	....	18	2	15	1 046	19	....	0	...	55–60
9	Chelsea, Mass.	C. I.	2–16	2 542	....	39 6	....	..	0 1	10	319	6	441	0	41	50–75
10	Cleveland, Ohio	C. I.	3–48	160 982	18 353	677 0	11 05	0 46	2 6	324	7 966	685	14 941	...	...	20–100
11	Fall River, Mass.	C. I.	6–24	.....	....	101 6	....	..	..	23	1 153	29	1 170	...	...	80
12	Fitchburg, Mass.	C. I., W. I., Cem. L.	2–30	2 214	....	72 6	....	..	..	13	593	10	660	...	...	75 & 165
13	Gloucester, Mass.	C. I., Cem. L.	1–20	5 130		63 1	27 31	0 07	19 6	3	303	12	483	152	27	15–75
14	Harrisburg, Pa.	C. I.	6–30	22 701	1 348	58	....	4	..	52	775	116	1 421	...	8	30–70
15	Haverhill, Mass.	C. I., Cem. L.	2–24	7 688	....	82	....	..	..	6	346	22	877	...	...	30–120
16	Holyoke, Mass.	W. I., C. I., Ld. I.	4–30	11 073	0	88 2	12 13	..	5 9	59	878	62	899	18	40	60–100
17	Lowell, Mass.	C. I.	4–30	27 778	....	140 5	....	..	2	42	1 271	82	1 441	30	34	17–72
18	Lynn, Mass.	Cem. L., C. I.	4–36	529	0	138	136 00	0 08	..	15	987	13	1 057	...	67	40–60
19	Madison, Wis.	C. I.	4–16	10 255	....	48 4	....	..	..	8	286	20	353	...	3	53–65
20	Marlboro, Mass.	C. I.	4–16	156	0	36 6	0 80	0 11	0 9	0	347	0	390	19	65	35–142
21	Met. W. W., Mass.	C. I., Cem. L.	6–60	.....	....	83 8	....	..	..	...	....	1	361	...	...	.....
	Met. Water Dist. (total in district supplied)	C. I., Cem. L., Kal.	4–60	14 16[1]	....	1535 1	....	..	..	198	13 690	...	....	...	...	.....
22	Middleboro, Mass.	C. I.	4–12	2 134	12	17 9	....	..	..	3	127	8	193	...	6	40–70
23	Minneapolis, Minn.	C. I., W. I., Steel.	1½–50	82 084	0	332 7	....	..	..	179	3 893	150	2 883	...	46	.....
24	New Bedford, Mass.	C. I.	4–36	13 448	2 545	106 3	7 95	0 10	0 9	34	1 105	34	1 272	114	105	25–95
25	New London, Conn.	Cem. L., C. I.	4–24	5 882	0	64	4 09	0 37	18 4	7	348	18	486	...	34	35–45
26	Newton, Mass.	C. I.	4–20	4 009	530	141 4	1 30	0 03	3 3	3	976	5	843	50	400	80–86
27	Oberlin, Ohio	C. I.	4–12	120	0	10 7	0	0	0 3	0	99	0	68	2	2	27–32
28	Plymouth, Mass.	Cem. L., W. I.	2–20	2 411	0	47 3	6 67	0 53	10 6	6	236	12	529	145	38	.....
29	Providence, R. I.	C. I.	6–42	68 414	5 945	362 7	....	..	0	46	2 107	164	3 891	0	41	64–73
	H. P. Fire System	C. I.	12–24	0	....	5 6	....	..	..	0	92	...	31	...	4	114
30	Reading, Mass.	C. I.	6–12	675	0	29 5	$1 53	0	0	0	165	2	265	0	14	63–78

30	Reading, Mass. . .	C. I.	6–12	675	0	29	5	$1	53	0	0	0	165	2	265	0	14	63–78
31	Reading, Pa. . . .	C. I.	2–36	12 268	3 458	109	9	25	92	1 6	0 7	31	909	81	2 752	9	...	10–133
32	Somerville, Mass. .	C. I.	4–20	5 369	....	91	3	0	86	0 09	..	17	1 067	18	1 376		136	35–100
33	Springfield, Mass. .	Cem. L., W. I., C. I.	1–36	20 687	9 252	156	8	3	37	0 14	7 0	39	1 174	137	2 377	469	90	90–120 H. S 30–35 L. S.
34	Taunton, Mass. . .	C. I.	4–20	1 493	0	82	1	....		0 15	1 6	8	877	7	623	12	60	35–120
35	Waltham, Mass. . .	C. I., Cem. L.	2–24	13 987	9 900	53	7	5	14	0 3	2 0	13	415	16	758	44	63	50–70
36	Ware, Mass. . . .	C. I.	4–12	0	0	12	6	....		..	1	...	121	1	128	13	3	90–95
37	Wellesley, Mass. . .	C. I., Cem. L.	1½–12	5 018	0	33	2	0	60	0 6	0 6	5	314	5	249	4	4	35–125
38	Westerly, R. I. . .	C. I.	4–16	288	0	34	1	....		0 09	..	2	163	2	213	...	...	.....
39	Whitman, Mass. . .	Cem. L., C. I.	1–16	.....	....	22	0	....		..	..	...	169	...	117	...	...	.....
40	Winchendon, Mass. .	C. I., W. I.	2–14	6 682	0	20	7	....		..	2 4	4	149	6	200	36	19	40–151
41	Woonsocket, R. I. .	C. I.	4–20	8 438	0	53	2	4	92	0 09	0	13	624	22	549	0	15	50–120
42	Worcester, Mass. .		2–40	.....	....	197	2	....		..	..	...	2 012	...	2 868	...	...	.....
43	Yonkers, N. Y. . .	C. I.	3–30	30 215	486	103	9	....		..	0 8	78	1 111	47	732	3	24	45–130

[1] Miles.

1906. — TABLE 5. — STATISTICS RELATING TO DISTRIBUTION SYSTEM. — SERVICE PIPES.

Number.	Name of city or town.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		SERVICE PIPE.					SERVICE TAPS.				METERS.				MOTORS & ELEVATORS.	
		Kind.	Sizes. (Inches.)	Extended. (Feet.)	Discontinued (Feet.)	Total in use. (Miles.)	Number added.	Total in use.	Average length of services. (Ft.)	Average cost of services for the year.	Number added.	Now in use.	Percentage of services metered.	Percentage of receipts from metered water. (B) ÷ (C)	Added.	Total in use.
1	Arlington, Mass.	C. I., Galv. I., Cem. Lined.	¾–6	....	...	...	58	1 877	...	$17 53	233	652	34	39	...	5
2	Attleboro, Mass.	.....	...	....	...	...	...	.....	...	.....	105	1 875	...	..	...	2
3	Belmont, Mass.	Cem. Lined, Galv.	1–6	3 325	68	7 7	44	754	76	31 82	44	754	100	..	...	...
4	Beverly, Mass.	Galv., Lead Lined.	¾–4	....	...	...	145	3 845	...	.....	16	139	...	..	...	...
5	Billerica, Mass.	W. I., Cem. Lined.	1–1½	333	...	3 8	5	278	...	.....	3	164	59	71	...	...
6	Brockton, Mass.	W. I., Ld. Lnd., Cem. Lnd., C. I.	¾–8	17 245	688	47 7	353	6 820	46 20	15 30 8 86	359	6 210	91	97	1	13
7	Burlington, Vt.	Galv., C. I., Lead.	¾–6	1 550	125	19 9	62	3 696	25	13 50	119	2 983	81	85	2	41
8	Cambridge, Mass.	Galv., C.I., Tin Lnd., Lead Lnd.	¾–8	4 835	...	117	129	15 062	37	17 51	82	2 935	19	..	...	...
9	Chelsea, Mass.	Lead.	¾–2	2 321	...	33 1	88	6 509	26	18 26	318	951	14	56	0	5
10	Cleveland, Ohio	Lead, Galv., C. I.	¾–16	....	...	...	4 436	67 519	14	.....	12 001	56 168	83	86	—6	131
11	Fall River, Mass.	Lead.	¾–2	....	...	...	101	7 845	...	.....	143	7 666	...	..	...	...
12	Fitchburg, Mass.	W. I., Cem. Lined, C. I.	¾–8	....	...	...	50	4 795	...	.....	81	3 149	...	..	2	117
13	Gloucester, Mass.	Cem. Lined, Galv.	1–6	2 296	...	15 6	120	3 968	20 7	36 40	6	218	6	22	...	...
14	Harrisburg, Pa.	Lead, Galv.	¾–6	....	...	...	420	13 879	...	.....	992	7 648	73	80	...	27
15	Haverhill, Mass.	Lead, W. I.	¾–2	3 920	...	44 3	98	5 796	40	16 00	41	753	12	26	1	20
16	Holyoke, Mass.	Cem. Lnd., Rub. Lnd., Enam., Ld. Lnd., Tin Lnd., Galv.	¾–4	1 280	17	15	81	3 881	20	15 00	10	318	...	..	2	112
17	Lowell, Mass.	Lead, Ld. Lnd., Tin Lnd., W. I.	⅝–2	10 384	...	87 5	285	11 719	36	29 63	501	8 377	71	84	...	...
18	Lynn, Mass.	Cem. Lined, Lead Lined.	½–4	22 400	600	109	397	13 953	40	18 00	466	4 590	40	60	...	4
19	Madison, Wis.	Lead.	¾–2	5 272	...	19 6	258	3 961	...	.....	282	3 865	98	..	...	...
20	Marlboro, Mass.	Cem. Lnd., Ld. Lnd., Lead, Galv.	½–2	366	0	9 4	21	2 290	18	11 52	58	34 01	59	71	...	19
21	Met. Water Dist.	.....	...	....	...	...	3 264	151 058	...	.....	4 257	22 233	...	..	...	...
22	Middleboro, Mass.	Cem. Lined, Lead.	¼–4	1 303	56	10 3	27	908	58	.....	26	439	47	69	0	7
23	Minneapolis, Minn.	Lead, Galv.	⅝–1	....	...	...	...	30 070	...	.....	5 742	19 276	...	..	0	8
24	New Bedford, Mass.	Lead, C. I.	½–10	14 713	741	71 9	287	10 764	35	18 50 5 37	371	2 803	26	60	10	167
25	New London, Conn.	Cem. Lined, Galv., Lead.	¾–4	2 856	133	12 2	157	3 873	18	11 73	27	416	10	..	0	6
26	Newton, Mass.	Galv., Tarred I., Lead.	¾–6	11 515	4 160	85 8	98	7 673	59	23 93	182	6 642	87	98	1	19
27	Oberlin, Ohio	Galv., Lead.	¾–4	....	0	...	34	922	14	8 50	82	672	85	92	0	0
28	Plymouth, Mass.	Lead, Cem. Lined.	¾–4	535	...	6 7	77	2 278	7	6 60	....	.....	...	..	0	1
29	Providence, R. I.	Lead, C. I.	½–10	....	...	...	652	25 094	...	.....	694	21 852	87	..	4	188

30	Reading, Mass. . .	C. I., Lead, Cem. Lined.	¾–6	4 423	87	17 1	41	1 246	108	$38 55	46	1 130	91	..	0	4
31	Reading, Pa. . . .	Lead, W. I., C. I., Lead Lined.	½–8	....	...	...	785	20 685[1]	...	....	401	1 893	9	25	58	71
32	Somerville, Mass. .	Lead, Ld. Lnd., Cem. Lnd., C. I.	½–6	8 520	...	74 1	210	11 489	...	21 13	738	2 829	25	41	0	9
33	Springfield, Mass. .	Lead, Cem. Lnd., Tarred, Galv., C. I.	½–8	....	...	...	229	11 175	...	....	556	4 850	45	46	11	308
34	Taunton, Mass. . .	Cem. Lined, Tin Lined.	¾–4	3 405	...	48 2	82	4 983	...	....	70	2 293	46	68	0	19
35	Waltham, Mass. . .	W. I., C. I.	¾–10	8 402	2 170	45 0	82	3 620	62	40 65	10	320	9	22	0	10
36	Ware, Mass. . . .	W. I., Cem. Lined.	1–2	629	15	10 2	10	827	62	....	15	834	94	..	0	10
37	Wellesley, Mass. . .	C. I., Cem. Lnd., W. I., Lead, Ld. Lined.	½–8	4 060	196	20 4	31	995	92	11 12	36	1 016	100	100	0	0
38	Westerly, R. I. . .	Lead, Iron.	½–4	3 481	0	...	47	1 624	11	10 05	48	1 374	85	91	0	9
39	Whitman, Mass. .	.....	..	....	...	...	70	1 248	...	....	63	700	...	..	...	...
40	Winchendon, Mass.	W. I.	1–2	2 274	0	5 7	48	657	47	9 87	35	619	97	99	0	1
41	Woonsocket, R. I. .	Lead, C. I.	¾–6	1 687	0	8 4	141	2 917	10	....	138	2 504	86	96	0	16
42	Worcester, Mass. .	.....	..	....	...	...	...	.....	...	....	....	14 466	...	..	...	...
43	Yonkers, N. Y. . .	Lead, C. I.	⅜–8	....	...	...	372	6 637	...	....	453	6 660	100	..	0	7

[1] Estimated.

COMPUTATION OF THE VALUES OF WATER POWERS, AND THE DAMAGES CAUSED BY THE DIVERSION OF WATER USED FOR POWER.

BY CHARLES T. MAIN, MECHANICAL ENGINEER, BOSTON, MASS.

[*Read September 12, 1907.*]

DEFINITION OF VALUE.

1. The following definition of market value was given to the witnesses who were to testify on values in a recent important lawsuit.

2. "'Market value' means the fair value of the property, as between one who wants to purchase and one who wants to sell any article; not what could be obtained for it under peculiar circumstances, when a greater than its fair price could be obtained; not its speculative value; not a value obtained from the necessities of another. Nor, on the other hand, is it to be limited to that price which the property would bring when forced off at auction, under the hammer. It is what it would bring at a fair public sale, when one party wanted to sell and the other to buy."

DEFINITION OF DAMAGE.

3. The definition of the damage due to the diversion of water was stated as, "The difference in market value, before and after the diversion."

METHOD OF DETERMINING VALUE.

4. The value of an undeveloped water power depends:

First. Upon its location, the amount and uniformity of flow, head, conditions affecting the cost of construction and transmission, use of exhaust steam and need of water for other purposes than power.

Second. Upon what the power is to be used for, whether for electric lighting and railway work, through most of the hours in the day with a variable load, for some use requiring a fairly steady

load for twenty-four hours a day, or for running a textile mill or similar plant with a fairly steady load for about ten hours a day.

Third. Upon the market which can be served, whether it is secure and steady or must be built up and is somewhat unreliable.

5. The value of a privilege should be determined by comparison with the cost of producing power in such quantities and with such regularity as is required for the particular purpose for which it is to be used in a fairly economical manner at any place or places equally convenient for the transaction of the business under consideration. Sometimes the location is fixed, but oftentimes there can be a choice of locations.

6. In estimating the value of an undeveloped privilege, the steps followed are as follows:

(1) Determine the flow, including the effect of storage and pondage.
(2) Determine the net head.
(3) Determine the horse-power which can be economically developed and used each month in an average year.
(4) Determine the minimum flow and power, and from this the size of supplementary steam plant required if the power is to be developed above the minimum flow.
(5) Determine the shortage of water power during such months as there is a deficiency.
(6) Estimate the probable cost of development of the water power.
(7) Estimate the probable cost of the supplementary plant, using steam, gas, oil, or anything which is best for the location under consideration.
(8) Estimate the yearly cost of running the water power and supplementary plants, including the fixed charges on both, to produce a combined power suitable for the purpose for which the power is to be used.
(9) Estimate the cost of a steam or other kind of plant, necessary to produce the power required.
(10) Estimate the yearly cost of running this plant, including fixed charges, to produce the power required.
(11) Subtract the cost of producing the power by water power and the supplementary plant from the cost of producing

it by steam power, or some other method, alone. The difference, if positive, gives the apparent yearly saving by the use of water power. The apparent saving should be modified if necessary for location or any other thing affecting the value.

(12) Capitalize this difference at a rate which seems proper, and the result is the value of the privilege.

7. There seems to be a great difference of opinion as to the proper rate of capitalization, but in the purchase of water power privileges the buyer of his own free will assumes certain risks, as damages caused by freshets, changes of business, etc., which he will not assume for nothing. He is also basing his comparisons of cost of power upon the present cost of producing power, which cost may be reduced in the future. For these reasons, the yearly saving should be capitalized at a rate not less than 10 per cent.

8. Where a whole property is taken and the owner is free to move into an equal or more favorable location, the method and rate of capitalization given above should be used.

If the privilege is developed the total value includes the value of the plant.

9. The value of a plant will be its cost, less depreciation, up to the point where the cost of water power equals that of steam or some other power. Beyond this point, when water power costs more than steam power, the value of the improvements, although new, would not be represented by the cost but would be something less than the cost. It is the sum which could be paid for it new which would bring the total cost of water power including fixed charges down to the cost of steam power, less depreciation.

METHOD OF DETERMINING DAMAGES.

10. The damage has been defined as the difference in value of the entire property before and after diversion.

11. It is usually unnecessary to go through an elaborate estimate of the value of the whole property, before and after the diversion, for the reason that many of the items of value will remain constant. The decrease in value, if there be any, is due to the fact that the running expense is increased by the diversion, and if this increased cost of running be capitalized at the proper rate

the capitalized sum will represent the amount which the property is decreased in value, or the damage.

12. In estimating the damage to an undeveloped or abandoned power, the value before and after diversion should be estimated as described under the previous heading. The difference represents the damage.

13. If a privilege is developed and used, a valuable business carried on and a plant established which cannot be easily moved, the definition of damage still holds good, but in such a case it is customary to capitalize the yearly loss at a smaller rate than 10 per cent., as this damage is done against the owner's wishes, and as he should receive a sufficient sum from which, in his business or in some other way, he can obtain a sufficient income to make good his yearly loss. The writer has, unless otherwise instructed, capitalized the yearly loss at 5 per cent.

14. A privilege which produces a variable power and has no supplementary power is not damaged any more than if it were so supplemented, and it should be treated in the same way as though it were supplemented.

15. The writer has generally used the following method of determining the damage to an established property, due to the diversion of some of the water.

(1) Determine the flow, including the effect of storage and pondage, before and after the diversion.
(2) Determine the net head.
(3) Determine the horse-power which can be economically developed and used before and after diversion.
(4) The difference between the power used before and after diversion is the power diverted which causes damage.
(5) Estimate the additional yearly cost of running caused by the taking away of this power, of coal, attendance, and supplies.
(6) If any permanent power has been taken, that is, power which can be relied upon in the lowest flow of the stream, estimate the cost of a steam plant or portion of plant necessary to make good the amount taken in the dry month.

(7) Estimate the fixed charges on this cost of additional supplementary plant.

(8) Add the extra cost of running and additional fixed charges and the sum represents the extra yearly expense.

(9) This extra expense capitalized at a proper rate represents the damage.

16. If it is necessary for the mills to maintain a steam plant of sufficient size to run the whole mill under the conditions existing before the taking, it is clearly not necessary for the defendant to furnish or maintain any further addition to the plant, and the damages consist of the increased expense of running the plant, already installed, due to the diversion.

17. If the total power required to run the mill is so large that the steam plant must be run all of the time, then there is no extra expense for attendance or supplies due to the diversion.

18. If the total power required is such that wheel plant can run the whole work for a portion of the year alone, and for the remainder must be supplemented by steam power, the time during which the engine must run may be extended by reason of the diversion, and in such case there is an addition to the expense of running for labor and supplies for such extra time, which should be added to the extra cost of coal, and the total extra expense capitalized at a proper rate will represent the damage.

WATERSHED AND RUN-OFF.

19. Too much stress cannot be placed upon the importance of determining the flow of the stream under consideration. If careful gagings have been made extending over considerable time they are the most reliable information which can be had. If no gagings have been made, an examination of the watershed should be made to ascertain its character, all existing rainfall records in the vicinity should be collected, and an estimate made of the run-off. Assistance may be had by comparison of similar rivers, the run-off of which is known.

20. The amount of data on the flow of streams which is available is increasing each year, as careful records are being kept on many rivers by persons or corporations who are interested in these matters, and by the United States Geological Survey.

21. The amount and uniformity of the run-off are two items which enter very largely into the value. The uniformity of flow depends largely upon the storage capacity and location of reservoirs on the watershed. The areas and capacities of such reservoirs should be ascertained and the net amount which can be drawn from them.

22. In estimating the average flow-off the months should be averaged in order of their dryness instead of in calendar order. If the flow is averaged by calendar months a great many irregularities in the flow are smoothed out and some of the flow is averaged which could not be held and used. By averaging all the dry months, all the second driest, and so on, some of this evening up is eliminated, but it cannot be altogether avoided. The average flow averaged by months in the order of their dryness will be less uniform and nearer the truth than when arranged by calendar months.

23. The average year is the one used in estimating the available power or power diverted, but the effect during the year when the flow is less than the average must not be lost sight of.

FLOW USED DURING WORKING HOURS.

24. The flow at any given privilege is usually given in cubic feet per second for twenty-fours hours a day and seven days a week.

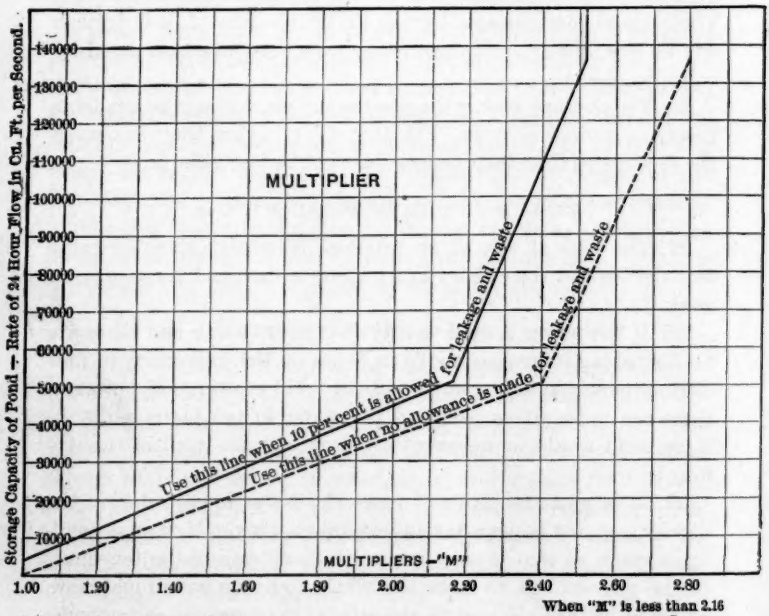
25. If the power is used twenty-four hours a day and there are no disturbing influences above to break up the uniformity of flow during the whole day, a small mill pond will answer. If, however, there are mills above using all the water in ten hours a day, a large pond would be necessary to store and use it all in twenty-four hours.

26. In a great majority of cases the water is used during the day for, say, ten hours a day and six days a week. If there is pondage enough so that it may be drawn down during the ten hours in the day enough to store the whole fourteen-hour night flow, and if no water were wasted, the ratio of the flow used in ten hours to the 24-hour rate would be 2.4; that is, 2.4 times the 24-hour rate of flow would be used during the ten working hours of the day. If the pond could be drawn down Saturday, so that the night and

Sunday flow could be stored, the ratio of 24-hour flow to that used in 10 hours a day and six days a week would be 2.8.

27. A certain amount of water is unavoidably wasted over the dam and by leakage through the various parts of the plant. This allowance of leakage and waste I usually place at 10 per cent. of the flow which could be theoretically stored and used. Using the above allowance for wastage, the maximum ratio of 24-hour flow to that which could be used in 10 hours, six days in a week, is $2.80 \times .90 = 2.52$.

28. When the pond cannot hold all of the flow during the time when the mill is not running, the ratio will be something less than 2.52, and when no portion can be stored the ratio is 1.



f—24 Hour Rate of Flow in C.F.S.
S—Storage in Cu. Ft.
M—$\frac{6}{10}$ the ratio, which the amount of Water which can be used 10 hours per day, 6 days in the week bears to the total amount flowing during the week.

Main, C.T.

When "M" is less than 2.16
"M"$= \frac{6}{10}\left(1+\frac{S}{86000f}\right)$

When "M" is greater than 2.16 but is less than 2.52.
"M"$= \frac{6}{10}\left(2.4+\frac{S-864000f}{216000f}\right)$

FIG. 1.

These ratios of amount of flow which can be used in 10 hours a day to the total flow have sometimes been called " multipliers." They are the figures by which the 24-hour rate of flow is multiplied to get the rate which can be used during the working hours.

29. The multipliers are computed for an isolated privilege by adding to the cubic feet naturally flowing in ten hours the cubic feet which can be stored each night, and to this adding one sixth the cubic feet which can be stored during the 24 hours of Sunday, and dividing this sum by the cubic feet naturally flowing in ten hours.

30. With a series of mills, some with small ponds might be enjoying the benefits of larger ones above, although they might have no rights in them. If the location were directly below the one with the larger pond, so that the lower privilege practically takes the water as it comes from the upper one, it will get the benefit of all or nearly all of the storage above. As the distance increases between the two privileges, the length of time required for the water to get to the lower one would increase and the benefit of the upper pondage would decrease. If it took one hour for the water to get down the multipliers would be 90 per cent. of those above; two hours, 80 per cent., and so on, plus any storage of water from the watershed below the upper privilege which can be stored in the lower pond.

31. Where there is a series of mills the multipliers can be computed in this way until a privilege is reached, where the multipliers due to its own storage are greater than those obtained for anything above. This power then becomes the governing one for those below it until another is reached having large enough storage to establish a new set.

32. The computation of these multipliers is tedious, and in order to facilitate the computation I have worked out the formula for them, and have prepared a diagram which reduces the labor to a comparatively small amount:

Let f = 24-hour rate of flow in cubic feet per second.

s = storage in cubic feet.

$M = \frac{9}{10}$ of the ratio which the amount of water which can be used in ten hours a day, six days a week, bears to the total amount flowing during the week:

36 000 = number of seconds in 10 hours.
50 400 = number of seconds in 14 hours, or one night.
216 000 = number of seconds in 60 hours, or one working week.
2.16 = 90 per cent. of 2.4 ratio of 10-hour flow to 24-hour flow.
2.52 = 90 per cent. of 2.8 ratio of 10-hour flow to 24-hour flow + $\frac{1}{6}$ of Sunday or 4-hour flow.

When M is less than 2.16,

$$M = \frac{p}{10} \left(1 + \frac{s}{36\,000\,f}\right).$$

When M is greater than 2.16 and less than 2.52,

$$M = \frac{p}{10} \left(2.4 + \frac{s - 50\,400\,f}{216\,000\,f}\right).$$

Fig. 1 shows the multipliers for various ratios of pondage to rate of 24-hour flow.

USE OF THE MULTIPLIERS.

33. The use of the multipliers is apparent when the problem is the determination of the amount of power which can be produced at a given place.

In estimating the damages caused by the diversion of a portion of the watershed, the power which can be produced before the diversion and the power which can be produced after diversion should also be estimated in the same manner, the difference between the two representing the amount of power diverted.

HEAD.

34. There may be several kinds of heads on the same development. There is the legal head, or the head to which the owner has a right to develop his power. This may or may not have been developed to its full extent. It may be that the expense involved would be too great to warrant further development. In some cases it might be economy to make the expenditure necessary to get the benefit of some unused portion of the head.

35. The gross head is the head actually used for producing power and getting the water to and away from the wheel.

36. The net effective head is the gross head minus the loss in head required to get the water to and away from the wheel.

This loss will vary with the length of the waterways leading to and away from the wheels, the velocity of the flowing water, and the construction of such waterways.

37. In several manufacturing cities where the water power is controlled by a company which is separate from the mill owners, there is an allowance of one foot made from the gross head before charging for the water as used on the wheels.

38. The head should be measured with the wheels running. The only portion of the head which produces power is the difference in level directly above and below the wheel when the wheel is running.

EFFICIENCY OF WHEELS.

39. Some tests of water wheels show a maximum efficiency of about 85 per cent. It is probable that over 80 per cent. is rarely realized in practice after wheels have been installed for a short time, and this is for three-quarters to full-gate opening. When the gate opening is less than about three-quarters, the efficiency begins to drop.

40. Fig. 2 shows an efficiency curve which has been published by one of the large wheel makers in their catalogue as the result of tests on one of their wheels. This is an excellent curve and represents a wheel of maximum efficiency which is not often found in practice.

41. After wheels have been run for some time the buckets and guides are not as smooth as when they are new, and the efficiency drops off. For these reasons I usually allow an average efficiency, for wheels running under ordinary conditions of age, repair, and variable gate opening, of about 75 per cent. Under exceptionally good conditions and where there are several wheels this could be increased.

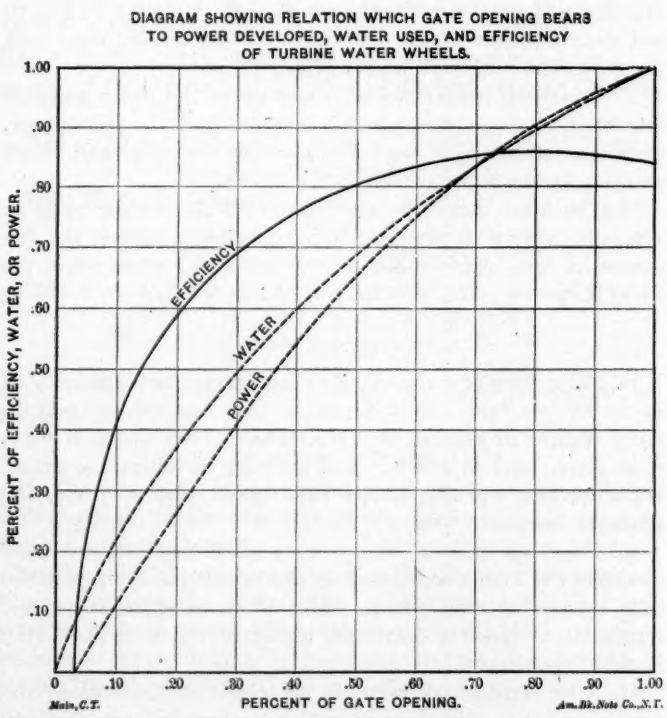


FIG. 2.

LIMIT OF LOW FLOW.

42. With vertical wheels and bevel gears, and belt drive to head lengths of shafting, the friction losses are probably from 5 to 10 per cent. of the total. With horizontal wheels the friction losses are probably from 2 to 5 per cent.

43. On Fig. 2 there is plotted in addition to the efficiency the percentage of water and of power produced for different gate openings. From this it will be seen that with a small flow the efficiency and the amount of power developed will be small, and unless the total drainage area is fairly large, or the low flow is sustained from storage, the power developed in dry months may

not be sufficient to run the wheel and overcome the frictional losses.

44. The flow required to produce 5 per cent. of the power is about 15 per cent. of the total water required to run the wheel full, and for 10 per cent. of power, 20 per cent. of water is required. With one wheel only there must, therefore, be a flow of say 10 to 20 per cent. of the total used by the wheel to produce any useful power. With several wheels properly arranged this could be reduced somewhat. At such times of low flow the water must either be stored and used for a short time in the day or it will produce no useful work.

EFFECT OF BACK WATER.

45. In a great many places there are periods during the year when the flow in the stream is so large that the water backs up below the wheel to a greater extent than the level of the water above the wheel can be raised, thus reducing the effective head and power. Sometimes the effect is so great as to prevent the use of the wheels.

EFFECT OF LOW FLOW AND BACK WATER.

46. The effect of low flow is to require an auxiliary power plant to make up the deficiency of water power, if it is necessary to run constantly, and if the flow drops so low as to produce no effective power, the auxiliary power plant must be of a capacity sufficient to run all of the work.

47. The effect of back water is to reduce the power produced by the water and to make it necessary to maintain a water power plant which has a surplus capacity in times of ordinary flow, or to maintain an auxiliary power plant and to run the same to make good the diminution of power if it is necessary to run full all the time. If the back water lasts for a long time and is so serious as to prevent any production of power from the wheels, the auxiliary plant must then be large enough to run the whole work.

LENGTH OF TIME DURING WHICH DIVERSION CAUSES DAMAGE.

48. In order to ascertain the difference in running expense due to diversion, it is necessary to know the average amount of power diverted and for how many months the diversion occurs.

This latter can usually be ascertained by knowing the capacity of the wheels in use, for in the majority of cases the wheel development will be an economical one.

49. It is sometimes the case, however, that larger wheels are installed than economy would warrant, by overestimating the flow, or some other cause. Wheels are sometimes installed to be used in times of back water, remaining idle at other times. Where the variation of the use of power during the day is large, as for electric light and railway purposes, wheels may be installed for the peak load where pondage will allow this method of running. If the length of time when the diversion causes damage is measured by the capacity of the existing wheels, it may appear to be for the entire twelve months of an average year. This cannot be true, for it would not pay to put in wheels to use all of the water in every month in the year. The diversion should be estimated for as many months as it would be economy to develop the power to use all the water under average conditions.

50. If the chance size of a wheel should be taken as measuring the length of time over which the damage continues, in a series of adjacent mills, some which had put in a portion of the wheel plant which could be used with economy would receive small damage, while a mill with a much larger wheel than would ordinarily be used would receive large damages thereby, when in point of fact the damage would be the same, other things being equal, and with a series of mills the damages would not be proportioned properly unless the wheels were installed in each on the same basis of economical development.

ECONOMICAL DEVELOPMENT OF WATER POWER.

51. In a large number of water power developments which I have examined, a very large percentage have been developed with wheel capacity sufficient to use all of the water from six to seven months in an average year, and during the remaining months water would go to waste. The economical development has been stated by some engineers to be nine months. No general statement is applicable to all conditions. It is a question of economics which requires solving for each particular case.

52. The factors which enter into the problem are on one side

the cost of the water power development and the fixed charges on the same, plus the cost of water if anything is paid for it, and on the other side the saving which can be effected by the use of such a plant.

53. The cost of the dam will be a constant for any size of wheel development, other things being equal. The head gates, canal, racks, feeders, wheels, wheel-pits, and tailraces must be increased in size and cost for the purpose of using a larger amount of water than the flow in the average month or sixth month of an average year, and the fixed charges for such increase in cost, plus the cost of water, represent the annual cost of the corresponding increase in water power.

54. The saving due to such increase in water power is represented by the saving in coal only on supplementary steam plant, necessarily run with such a varying water power, plus the cost of attendance and supplies on steam plant if it can be shut down entirely during the months of maximum power on the wheels. As the water power is increased in size to use water for a greater number of months, the cost of such increase for each additional month makes a saving for a less number of months, and there comes a time when the saving on steam power is less than the fixed charges on the additional cost of water power plant. Where these two items balance depends upon the following conditions:

(1) Cost of running the water power plant for each increment of power.
(2) Saving effected by the decreased use of steam power.

55. The variation in the cost of the water power plant per horse-power is very large. The principal causes for this are the variation in head and distance from the source of supply of the water to the point of discharge. The cost of construction will also vary with local conditions.

56. The saving effected would also vary largely, depending principally upon the number of hours run during the day, the cost of coal, and whether by increasing the size of water power plant the auxiliary power plant could be stopped during the months in which the water power was producing full load.

57. An example will suffice to make this clear. Supposing

the cost for each additional horse-power of water power plant required to use all the water for a longer period was $60 a horse-power. The fixed charges on this, including interest, will be not less than 8 per cent., or $4.80 per year. The cost of coal and attendance on a steam plant of say 500 horse-power, when running ten hours a day, with coal at $4 per ton, is about $13 per year per horse-power, or $1.08 per month. $4.80 ÷ $1.08 = 4.44 months. In other words, it would not pay to develop such a power to use all the water for more than about seven and one-half months.

58. If the engine or boilers cannot be shut down at all, a less saving could be made and the power could be economically developed for a less period than seven months.

59. The various conditions and lengths of time required to have the saving equal the fixed charges are shown in Fig. 3. This diagram is figured on coal at $4 per ton, and with a running time of ten hours a day, six days a week. Similar diagrams could be made for any other prices of coal and time of running.

60. To use the diagram, supposing the water power plant cost $50 per horse-power, and the size of steam plant is 200 horse-power. On the ordinates find $50 cost of water power plant. Run along horizontally until this line intersects the vertical line of 200 horse-power of steam plant, and these two lines will be found to intersect about on the curve marked three months.

If the water plant cost $70 and the steam plant were 350 horse-power, the time is five months during which water should waste.

TABLE SHOWING FLOW AND POWER.

61. The table on page 232 shows a convenient form for tabulating the flow and power. The first half is useful in estimating the value of a privilege, and the whole table for estimating damages when a portion of the flow is diverted.

62. The only thing needing explanation is the figure .0851 which appears in the headings of columns 6 and 12. This is the horse-power produced by one cubic foot of water per second on one foot head with an efficiency of 75 per cent. With 80 per cent. efficiency the figure is about .091.

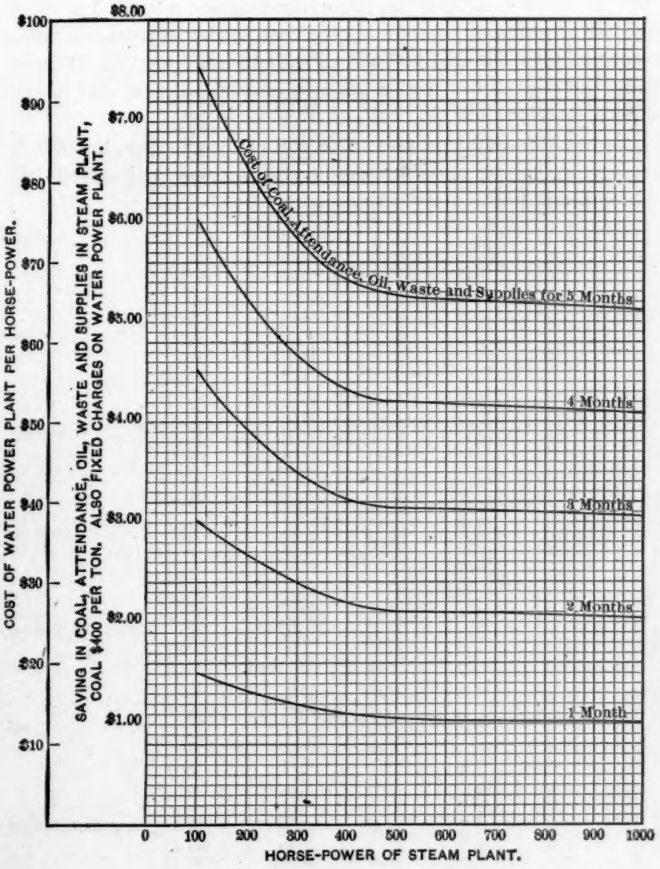


DIAGRAM SHOWING NUMBER OF MONTHS WHEN WATER SHOULD BE ALLOWED TO WASTE WITH DIFFERENT SIZES OF STEAM PLANTS AND DIFFERENT COSTS OF WATER POWER. Main, C.T. Am. Bk. Note Co., N.Y.

FIG. 3.

APPROXIMATE COST OF WATER POWER DEVELOPMENT.

63. In connection with the preceding diagram is printed a table, page 231, showing approximately the cost per horse-power of water power plants, not including dam, canal, and buildings, for different heads, distances from feeder head to end of tailrace, and horse-power of development.

It is not expected that this table will cover all cases, but it will give approximate figures for ordinary conditions, and is useful in making rough preliminary estimates.

TABLE OF ESTIMATED COSTS PER HORSE-POWER OF WATER POWER PLANTS

Having Horizontal Turbines, Steel Penstocks, and Walled Tailraces —Dam and Buildings not Included.

	"L".	10-ft. fall.	15-ft. fall.	20-ft. fall.	30-ft. fall.	40-ft. fall.
1,000 H.-P.	100 feet	$65.14	$40.92	$29.37	$19.40	$14.59
	200 "	71.91	45.48	32.84	21.70	16.38
	300 "	78.66	50.05	36.30	24.01	18.17
	400 "	85.43	54.62	39.77	26.32	19.95
	500 "	92.20	59.18	43.23	28.63	21.74
	600 "	98.96	63.75	46.69	30.94	23.53
900 H.-P.	100 "	65.35	41.00	29.56	19.56	14.79
	200 "	72.08	45.58	33.04	21.85	16.60
	300 "	78.80	50.16	36.53	24.14	18.41
	400 "	85.50	54.74	40.01	26.41	20.22
	500 "	92.24	59.32	43.49	28.70	22.02
	600 "	98.96	63.91	46.97	30.99	23.84
800 H.-P.	100 "	65.48	41.10	29.65	19.68	14.99
	200 "	72.22	45.68	33.12	21.98	16.78
	300 "	78.95	50.26	36.68	24.28	18.57
	400 "	85.70	54.84	40.04	26.56	20.35
	500 "	92.43	59.41	43.52	28.87	22.14
	600 "	99.15	64.00	46.98	31.17	23.93
700 H.-P.	100 "	65.72	41.19	29.87	19.90	15.12
	200 "	72.48	45.75	33.35	22.19	16.93
	300 "	79.23	50.30	36.82	24.49	18.73
	400 "	86.00	54.86	40.29	26.77	20.54
	500 "	92.74	59.42	43.77	29.07	22.34
	600 "	99.50	63.97	47.25	31.37	24.16
600 H.-P.	100 "	65.86	41.56	30.00	20.02	15.37
	200 "	72.64	46.14	33.49	22.34	17.20
	300 "	79.42	50.73	36.97	24.64	19.04
	400 "	86.20	55.30	40.45	26.95	20.87
	500 "	92.98	59.88	43.94	29.27	22.70
	600 "	99.76	64.47	47.42	31.57	24.54
500 H.-P.	100 "	66.00	41.70	30.24	20.24	15.52
	200 "	72.82	46.32	33.78	22.56	17.31
	300 "	79.64	50.94	37.28	24.86	19.10
	400 "	86.46	55.56	40.80	27.16	20.88
	500 "	93.28	60.16	44.34	29.48	22.66
	600 "	100.10	64.80	47.84	31.80	24.44
400 H.-P.	100 "	66.28	42.03	30.55	20.79	16.00
	200 "	73.16	46.65	34.05	23.10	17.82
	300 "	80.03	51.26	37.53	25.40	19.64
	400 "	86.90	55.88	41.03	27.73	21.45
	500 "	93.78	60.50	44.53	30.03	23.27
	600 "	100.65	65.13	48.03	32.35	25.08
300 H.-P.	100 "	66.87	42.67	31.09	21.49	16.50
	200 "	73.70	47.30	34.57	23.83	18.33
	300 "	80.54	51.94	38.07	26.18	20.16
	400 "	87.33	56.54	41.54	28.53	22.00
	500 "	94.17	61.18	45.04	30.88	23.83
	600 "	101.00	65.78	48.51	33.22	25.67
200 H.-P.	100 "	68.50	44.22	32.45	22.61	17.60
	200 "	75.35	48.84	35.97	24.97	19.47
	300 "	82.25	53.45	40.04	27.33	21.34
	400 "	89.10	58.10	43.56	29.70	23.21
	500 "	96.00	62.70	47.08	32.06	25.08
	600 "	102.85	67.35	50.60	34.43	26.95
100 H.-P.	100 "	71.39	46.64	34.76	24.75	19.80
	200 "	78.43	51.37	38.39	27.17	22.00
	300 "	85.47	56.10	42.02	29.59	24.20
	400 "	92.51	60.83	45.65	32.01	26.40
	500 "	99.55	65.56	49.28	34.43	28.60
	600 "	106.60	70.28	52.91	36.85	30.80

Note: "L"—Distance from Feeder Head to end of Tailrace. Cost of Canal, if any, not included.

TABLE ..... NAME .....

	Flow and Power before Diversion.								Flow and Power after Diversion.						Power Diverted.
Col. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Months in the order of their dryness.	Natural flow in cu. ft. per sec. on one square mile.	Total flow cu. ft. per sec. = Col. 2 × square miles.	Multiplier or ratio of flow which can be used in 10 hours to 24-hour rate.	Total flow which can be used in 10 hours a day = Col. 3 × Col. 4.	H.-P. which can be used in 10 hours a day on one foot fall = Col. 5 × .0851.	Total H.-P. which can be used in 10 hours a day = Col. 6 × ft. head.	H.-P. which present wheels can use or which would ordinarily be developed.	Total flow cu. ft. per sec. = Col. 2 × square miles.	Multiplier or ratio of flow which can be used in 10 hours to 24-hour rate.	Total flow which can be used in 10 hours a day = Col. 9 × Col. 10.	H.-P. which can be used in 10 hours on one foot fall = Col. 11 × .0851.	Total H.-P. which can be used 10 hours a day = Col. 12 × ft. head.	H.-P. which present wheels can use or which would ordinarily be developed.	H.-P. diverted which causes damage = Col. 8 − Col. 14.
Driest.....														
2d "														
3d "														
4th "														
5th "														
6th "														
7th "														
8th "														
9th "														
10th "														
11th "														
Wettest.....														
Totals and Averages...														

Average H.-P. diverted ..... for ..... months in an average year .....

EXTRA LENGTH OF TIME WHICH STEAM PLANT MUST RUN ON ACCOUNT OF DIVERSION.

64. If the power of the stream before and after diversion, is worked out it will probably be found that the auxiliary power plant must be run for a longer time after the diversion.

65. This would be shown in full months in the tables showing the power before and after diversion, but it would not show fractions of a month.

66. The method of ascertaining the extra length of time is shown in Fig. 4. The ordinates show horse-power which the whole stream can produce and the abscissæ the number of working days. By plotting the horse-power which can be developed before and after diversion, and drawing diagonal lines from month to month, the extra number of days when the auxiliary plant must run is shown where the diagonal lines cross the horizontal line of wheel development.

DIAGRAM SHOWING EXTRA LENGTH OF TIME WHICH ENGINE WOULD HAVE TO RUN IF INSTALLED AFTER DIVERSION.

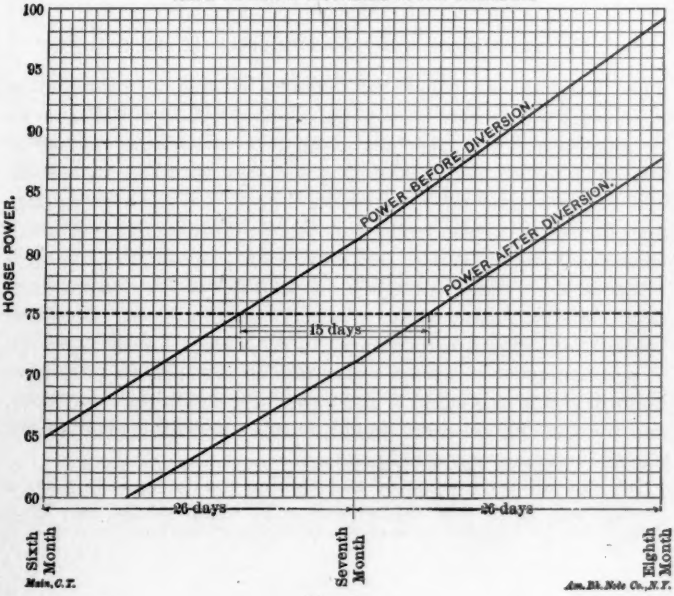


FIG. 4.

STEAM OR OTHER POWER PLANT TO BE USED IN MAKING GOOD THE POWER DIVERTED.

67. In order to determine the damage, it is necessary to estimate the cost of replacing the power taken away, not necessarily by the auxiliary plant already existing at the mill, for such a plant may be an extremely uneconomical one and the mill which had the poorest plant would get the most damages, but by a *fairly economical plant of the size and character such as the business under consideration would naturally use.* Unless this method is pursued with a series of mills, the one which had put itself into the best shape would receive a smaller amount of damage than its neighbor where things were in bad shape.

68. It is improbable that a concern would go on putting in each time it renews its plant an uneconomical plant, and it is highly probable that the low-grade engine will be improved in efficiency.

As the damages are figured forever, it will add very little to the damages for the comparatively short time which the uneconomical plant will be obliged to run.

PRIVILEGES WITH NO AUXILIARY PLANT.

69. The basis on which the damages should be estimated in these cases where there is no auxiliary power plant is the same as for any other. The mere chance that an owner can manage in some way to run his business in accordance with the fluctuating flow of the stream does not entitle him to any greater damage than his neighbor who is fitted up to run continuously. A small amount of power diverted will not make the conditions enough worse in most cases to require the addition of a supplementary plant for that reason alone. An allowance, however, should be made in estimating the damages in such cases for such portion of a steam plant as would ordinarily be installed to produce a uniform power as is equal to the power diverted in the dry month, and the running expenses should be estimated on a plant of full size and not on a very small plant.

70. The proper method of ascertaining the damages to a plant of this sort is to find the difference in value before and after

diversion, and this is obtained by finding the cost of producing a uniform power before and after diversion.

ALLOWANCE FOR PERMANENT POWER DIVERTED.

71. If any power is diverted which can be depended upon all the time, an allowance should be made for this. If the diversion is comparatively small the fixed charges should be allowed on the cost of a portion of the large plant equivalent to the amount of power diverted. Thus, supposing 5 horse-power is diverted in the dry month, and the cost of the steam plant is $60 per horse-power: 5×$60 = $300. $300 @ 12% = $36. This capitalized at 5% = $720.

If this allowance is made the owner may increase the capacity of his plant by 5 horse-power when he renews it, and will have been recompensed for this expense.

If the interest charges are not included in the fixed charges, the cost of plant, $300, should be added to the capitalized sum.

If the diversion is a comparatively large amount, it may be necessary to remodel and increase the existing steam plant, or to put in a new one. Allowance should be made in the same way for this.

COST OF STEAM POWER.

72. The cost of steam power usually has an important bearing upon the settlement of damages. The accompanying Figs. 5, 6, and 7 have been prepared, which show the yearly cost of producing steam power under various conditions and costs of coal when running ten hours a day and six days a week with a fairly steady load. They are intended to show the expense of running under everyday conditions on such a plant as a prudent man would install and run with ordinary skill.

The cost of 24-hour power for 365 days a year is about 2.2 times the cost for 10-hour power for 308 days.

The cost of 24-hour variable load cannot be stated without knowing all the conditions.

COAL CONSUMPTION USED IN ESTIMATING DAMAGES.

73. The coal consumption used in estimating damages when the power diverted must be made good under a varying load contingent

upon the fluctuation of the water power should be somewhat larger than the coal consumption for a fairly steady load. I have usually added about 20 per cent. to the coal consumption required for a steady load. The fluctuation of the water power will usually

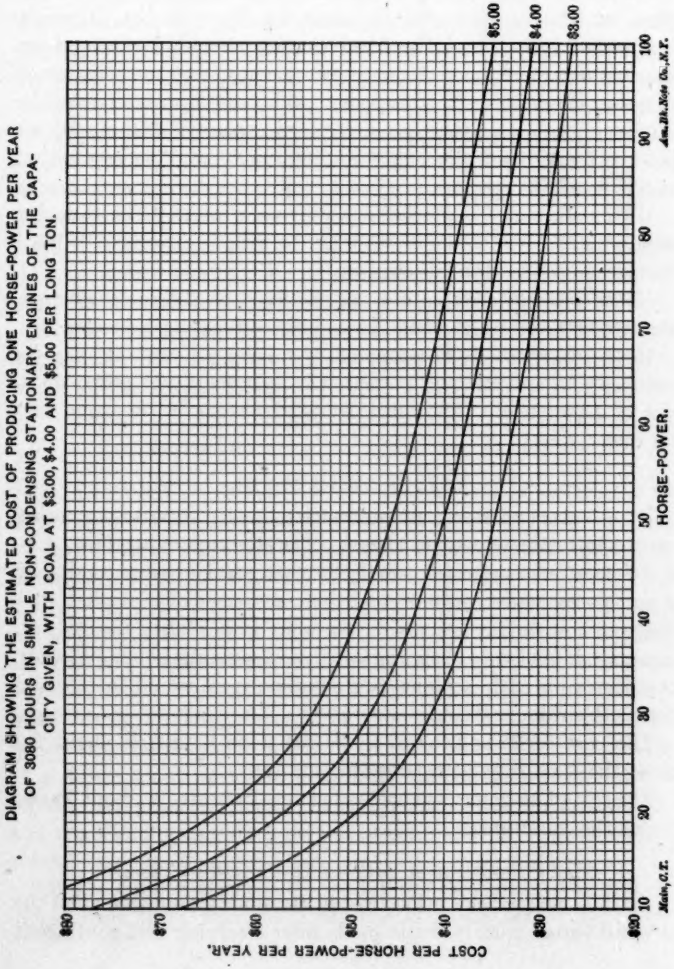


FIG. 5.

not be great for a single day, but the variation covers longer periods, as weeks or months.

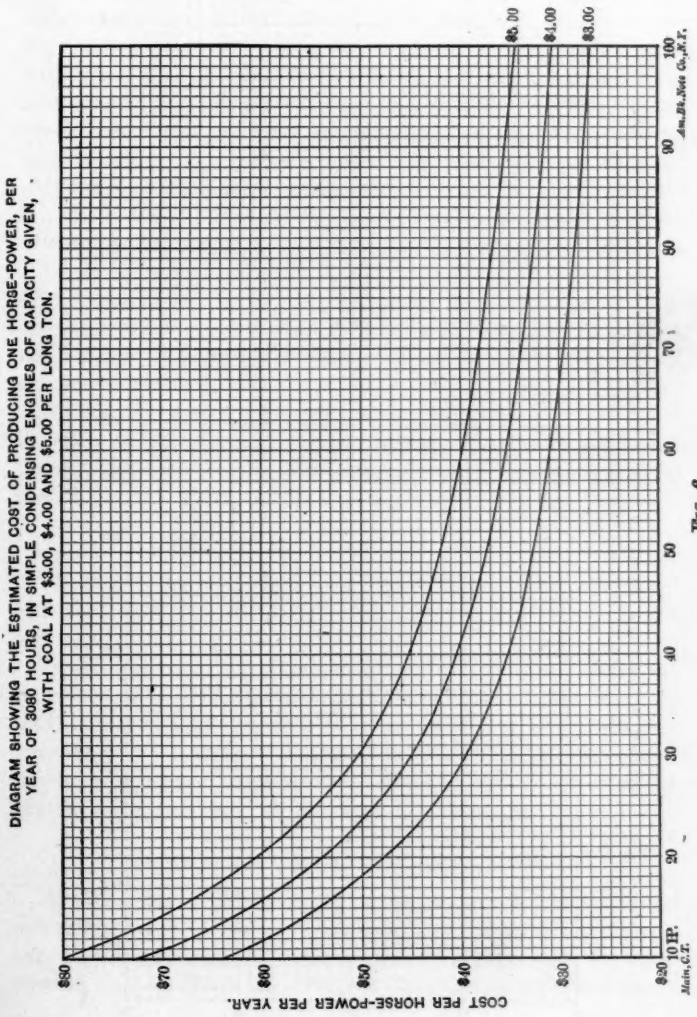


FIG. 6.

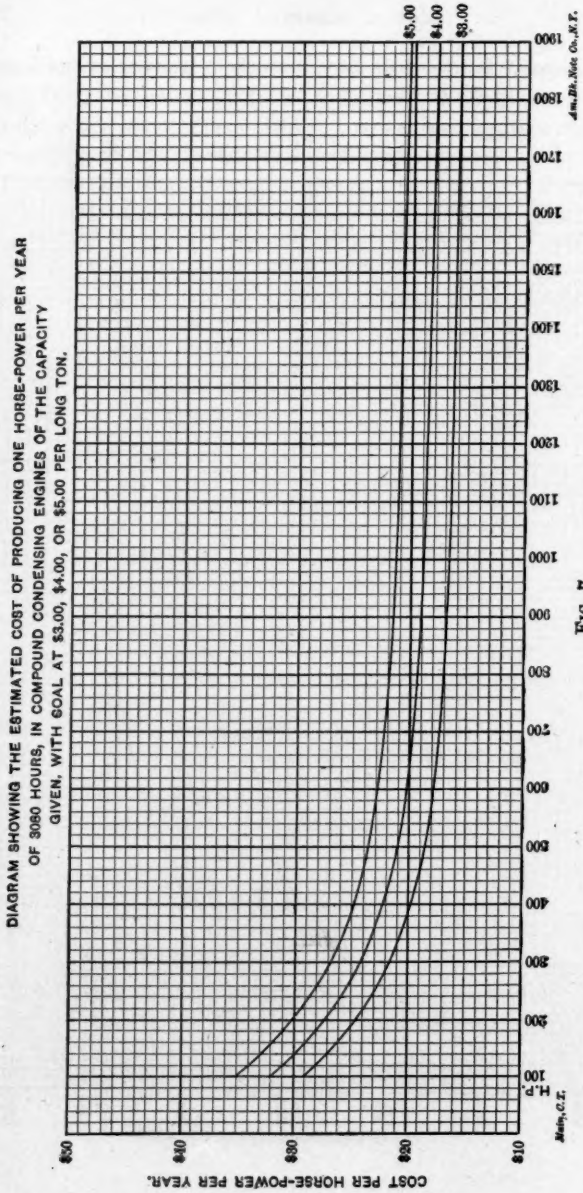


DIAGRAM SHOWING THE ESTIMATED COST OF PRODUCING ONE HORSE-POWER PER YEAR
OF 3080 HOURS, IN COMPOUND CONDENSING ENGINES OF THE CAPACITY
GIVEN, WITH COAL AT $3.00, $4.00, OR $5.00 PER LONG TON.
$5.00
$4.00
$3.00
H.P.
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
$50
$40
$30
$20
$10
COST PER HORSE-POWER PER YEAR.

Fig. 7.

EFFECT OF USE OF STEAM FOR OTHER PURPOSES.

74. In many textile and other mills low-pressure steam and hot water can be used in the manufacturing processes, and for warming the buildings. The amount varies largely, in some cases being more than the equivalent amount of steam exhausted from an engine large enough to run the work, or to the amount of water required for condensing for an engine of the same size. Rarely in a textile mill would the amount fall below 20 per cent. of the total heat rejected by the engine. This has the effect of reducing the value of water power for such mills, and has the effect of reducing the damages as figured on straight power conditions.

75. It is never attempted, however, to estimate this effect in suits for damages. It should be considered in estimating values, and it has its effect upon the selling value of water powers, making them of less value for industries having use for low-pressure steam and warm water.

76. All of the varying conditions of different industries have an effect of producing a sort of average selling value for water powers, but each case requires examination and estimates of its own.

EFFECT OF ELECTRICAL TRANSMISSION.

77. The statement is frequently made that water powers have increased in value since it became possible to transmit power electrically.

78. To be correct the statement should be modified. Since the introduction of electrical transmission many water powers which were before unavailable and valueless have been developed and become of value, and many others will be in the future, but water powers which have been developed and the power used adjacent thereto have, as a rule, not increased in value.

DETERMINATION OF VALUE OF REMOTE POWERS.

79. All of the preceding described methods are applicable to the determination of the value of a remote water power which may be capable of development with electrical transmission to some market, but there must be added one or two steps in the process.

80. To the cost of the development must be added the cost of the electrical apparatus and pole line to a point where the power is to be used, and this is a large item of expense in long-distance transmission. Usually, also, there must be added to the cost of the physical part of the plant a considerable amount for right of way for pole line, legal expenses, and cost of financing the scheme.

81. To the running expenses must be added the fixed charges for the electrical apparatus and pole line, and the cost of running and maintaining the same.

82. A correction must also be made for the loss of power in transmission.

83. A comparison of the cost of producing and transmitting power can be made with the prices which can be obtained for this power to determine if the development has any value, and whether the development is warranted or not. The price which can be obtained for the power depends largely upon the cost of producing power by steam, or in some other way, at the point of delivery.

POWER USED FOR ELECTRIC LIGHTING AND RAILWAYS.

84. In the majority of developments for electrical transmission the power is used to a large extent for electric lighting and railways; sometimes, in addition, for manufacturing purposes, and occasionally for manufacturing only.

85. When used for lighting and railways the power is usually exceedingly variable, resulting in a low power factor. The conditions are so variable that it would be useless to try to show in this paper the probable cost of power produced by steam under such varying conditions. Each case must be worked out to meet the special conditions of the problem under consideration.

DAMAGES CAUSED BY THE DIVERSION OF WATER POWER.

BY CLEMENS HERSCHEL, CONSULTING ENGINEER,
NEW YORK CITY.

[*Presented September 12, 1907.*]

A full discussion of this subject necessarily treats of legal matters about as much as it does of hydraulic or other engineering. It must, indeed, be founded on a consideration of the fundamental rule of law, frequently quoted, that the measure of damage done a piece of real estate by the diversion from it of a certain quantity of water hitherto flowing through it is the difference between two market values of that piece of real estate, the one estimated or judged as of date before the taking of the water right; the other appraised as of date after that taking.

Two sums of money are to be attained or determined in the minds of the masters or other tribunal charged with the duty of awarding the damage done or suffered in such cases, and their difference is the sum of money to be awarded to the claimant. Nothing simpler, one is tempted to say at the beginning of such hearings; only a simple sum in subtraction to be performed. And yet no class of cases has probably given rise to greater wrangling or presented at times a more lamentable spectacle of the incompetency of man to undertake the perfect administration of that one of the highest of divine attributes — the administration of justice.

There is, we will assume, no dispute as to the work to be done so far described, no dispute as to the rule of law to be applied as it has been above stated. Let us, therefore, briefly comment on the words and language of the statement made and recall some elementary principles and definitions not always present in the minds of laymen to the law, but to which experts in engineering must give due heed if they would aid in the administration of justice and be experts in fact as well as in name.

Our comments may follow the order of words as above written in stating the rule of law to be followed, and we thus come upon the words "real estate."

(1) These cases deal with damage to a piece of real estate.

They do not ordinarily deal, certainly not as far as the engineering expert is concerned, with damage done to the business carried on upon this real estate, nor with that done any particular individual. It is the real estate that is damaged, and it is this injury which is to be measured by a difference in its market values at two different dates.

(2) *Diversion of Water.* It may be hardly necessary to state that, inasmuch as all flowing water, as a rule, is held appurtenant to real estate, when some or all of this flowing water is prevented from reaching such real estate, an act of what is called diversion has taken place, and this causes the damage in such cases complained of.

(3) *Market Value.* A sum of money that can only be arrived at by the opinion of a properly constituted tribunal from evidence put before it, or generally by a concensus of opinion of men having knowledge of market values, that is, of the values of such property as it is bought and sold in a market that is neither stimulated nor constrained; that is, in a natural, open market, as between a party ready to sell and another willing to buy.

At first it might seem to an engineer as though the simplest way to compensate for the diversion of water from a piece of real estate would be by turning an equal quantity of water into the stream from some new source of supply, such as a storage reservoir to be constructed for that express purpose, and which would supply, when needed, water which had been stored out of freshet river flow; which not only was not needed, but might even be detrimental to others, the claimant included, if not thus withdrawn and stored in times of high water. Especially does it seem strange to an American engineer that this method of paying for water diverted by the gift to the parties injured of a compensating reservoir, as it is called, is not followed in the United States, when he knows that for a hundred years or more this has been and yet is the accepted method in Great Britain.

Many years ago, not being able to cause any one, learned or unlearned in the law, to give a satisfactory answer to my inquiries on this point, I had to study it out for myself, and was obliged for this purpose to import several acts of parliament authorizing the construction of such compensating reservoirs. Acts of this sort,

being of mere local concern, are not likely to be found elsewhere than in Great Britain, even in the best of law libraries, but a reading of them is extremely instructive in more ways than one; among others as illustrating the gulf that separates the rights, duties, immunities, and privileges of the citizen of Great Britain from those of a citizen of these United States. From such an act of parliament it quickly appears that, whereas a citizen of the United States lives under a government in which the legislature may enact laws, but cannot act as a judicial body (except in cases of impeachment), nor perform executive work, and the judicial and executive branches of the government are similarly each strictly confined to its own branch of government work, "to the end," as says the constitution of the good old Commonwealth of Massachusetts, "that this may be a government of laws and not of men"; the parliament of Great Britain, on the other hand, has powers "so transcendent and absolute that they cannot be confined, either for causes or persons, within any bounds."

And we find, in fact, that parliament, through its committees, habitually sits as judge and jury and awards damages, when it considers private legislation, and puts its awards into the clauses of such acts; nothing of which work any of our legislatures nor Congress can possibly do. It is under these powers of parliament that compensation reservoirs have been and continue to be built in Great Britain, with minute directions how they are to be maintained and operated, and, if desired, parliament could itself operate them.

Then, again, the state cannot authorize any one to "take property without just compensation"; and it is a settled principle of law in this country that a "just compensation" must consist of money paid over, and cannot consist of anything else. Every person has, moreover, the right of an appeal to a jury of his peers and countrymen at some stage of the proceedings, to say what amount would be a just compensation, and cannot be deprived of this, his right of appeal. So that though such compensating reservoirs have repeatedly been proposed, and in one instance — some sixty years ago, at the time of the construction of the first (the Cochituate) water works to supply Boston — were actually built, they could not be used to pay damages by substituting water

delivered for water diverted. Whence it appears that, stating cause and effect in juxtaposition, we may say that when Montesquieu, in 1748, in his " Esprit des Lois " (The Spirit of Law) first stated the necessity in a free state of separating the duties of the legislature, the executive, and the judiciary from each other (a principle which, as is well known, was adopted by all the American constitution builders of the eighteenth century), he decreed that American engineers could not build compensation reservoirs to pay for water diverted.

At first glance this may seem a result that is deeply to be regretted, so perfect, physically, is the form of compensation for water diverted made by water supplied. But there is a good deal to be said on the other side, and, as usual, it is weak human nature that is at fault. The difficulty comes in the course of time, on account of failure to compel the responsible parties properly to keep in repair and operate the compensating reservoirs year after year without pecuniary interest in having it done, and on account of the manifold changes of value that take place in the life and interests of the people. So that, for one, I have come to the conclusion that Montesquieu, in 1748, builded wiser than he knew in the matter of compensation reservoirs, and that for a practical, live people the payment of damages in money, the full and complete settlement of damages as they arise, and by the generations as they pass across the stage of life, is the better way.

It has been suggested that a city, by obligating itself to maintain and operate certain compensation reservoirs, could show that it had not diminished certain water rights, hence that no damage had been done, and there would be no damages to pay. But a jury would have to decree to that effect; a riparian owner has the right to have the water flow through his estate " without alteration," whether he were injured or not, and even were he benefited for the time being. In the United States he must be paid damages in money if he wants them, and he generally does.

We have seen that a substitution of water for water diverted is unlawful and impossible in payment of damages in the cases we are considering. Equally so should be, but with uninformed tribunals is not always, the substitution of steam or other caloric or transmitted power for water power diverted. Such substitu-

tion offends against the rule of law quoted, which is based wholly on market values, and justly so, as will plentifully appear. Suppose, for example, that the water power taken were situated within the site of a storage reservoir, to be buried eventually under 50 feet or more of water. If now a computation were made for that case of any form of substitution of steam power, the whole of the water power being taken, it would result in a computed award made by the engineering expert that would have no proper relation to and might be twenty or thirty fold the market value of the real estate taken, either before or after the diversion of the water under consideration. That is to say, it would have no application whatever to the case in hand; it would be wholly irrelevant and out of place for the expert to give it, and going further, he should know or be taught that such testimony is not aiding the court in its work. And if such testimony is wholly wrong or mistaken in one such case, because it does not instruct as to market values, the like testimony in other cases, if of no instruction in market values, is equally improper and may be grossly misleading.

Here, indeed, is the true test of such scientific or engineering testimony: Will it instruct experts in market values, or has it no readily discernible connection with market values? If the former, it is good; if the latter, it can only mislead.

Other cases repeatedly come before the masters in such cases in which the estimated values of substituted steam power have no direct bearing or give no instruction upon market values before and after the taking of the water diverted.

Such are the damages to an undeveloped mill site; to a mill driven wholly by water power in a place where steam power is a practical absurdity, and many more. There is every degree of bearing upon market values of testimony relating to steam power; from cases of no bearing at all of the cost of a substitution of steam power, such as have been cited, to those of the cost of a little extra coal burned on account of a minute percentage of diversion, which, in the mind of the buyer and seller in the market, may form an approximate indication of effect produced; from which, again, by a concensus of such opinions, the effect of the diversion on the market value may be arrived at.

If the rule of law first above quoted is good, it must be applied to all cases of damages to real estate by a diversion of water. It cannot be ignored where palpably it will not apply,—such as in the case of the reservoir site above referred to, or of the place where steam power is an absurdity, or of the undeveloped mill privilege,—and then adopted and values of a substituted steam power used in other cases.

If it is a rule of law, as we are told it is, it must hold in all cases; not have one law for the rich in opportunity and another for the poor.

Strictly speaking, all such cases require two distinct sets of experts, the one to measure the damage done in horse-power diverted and similar damage done; the other, consisting of assessors, real-estate agents, parties who have bought and sold mill property in the vicinage, etc., to appraise the value of the property before the diversion, and to appraise what that property was worth in the market since the acts complained of had taken place; which latter appraisal they may properly base on the results of the computations made by the first-named set of engineering experts.

Engineers with experience in cases of this class know that claims of ten fold and twenty fold the awards finally made, and of a *twentieth part of a water right* being computed worth more than the *whole piece of real estate* originally was worth, are no rarity, and are based on the computed cost of a substitution of steam power, capitalized, for the water power diverted. Engineers are responsible for the appearance of such claims in such cases, which would not appear and could not appear under a consideration by them of market values and of the rule of law noted. So absurd have these computed damages been in the past, being based simply on the capitalized cost of a number of horse-power equal to that of the water diverted, that able engineers, Mr. Main as a leader among them, have mitigated such computed damages by assuming a certain steam power present, and computing merely the cost of the additional fuel or power needed, after the diversion has taken place, to maintain the former total output of power per annum. This undoubtedly is more instructive as to the effect of the water diversion on market values, for the market is composed of both

buyers and sellers, and the average man in the market is, after all, Carlyle to the contrary notwithstanding, no fool out of the "1 500-000 000 inhabitants of the earth, mostly fools." But the principle must not be lost sight of, that we are establishing in the trial of such cases *two market values*, and the business of the engineering experts is to aid the appraisers of such values in the case in hand to reach a conclusion on market values; and it is not for the engineers to compute what the damages in dollars and cents in such cases may have been if based on any form whatever of substitution of steam power for water power; any more than it is to estimate the cost of bringing in additional or substituted water power or transmitted electric power, or any other power, and calling that the measure of damages. If the results of computations offered do not square with sensible market values, this will constitute proof positive that the methods which were followed by the computer were in error, and hence that they can not with propriety be used by him or any one else.

Closely allied with this subject is the broader one of the "Best Use to be Made of Experts in the Conduct of Judicial Inquiries." It would lead too far, however, to attempt here a discussion of that subject. It was treated at length by the present writer in 1886 in a paper which was printed by "Direction of the Committee of the Bar Association of the City of Boston on the Amendment of the Law."

If this class of cases were more frequently tried in any one community, the awards to be made would, no doubt, speedily reach a normal measure. That is to say: — within limits, a market value for such damages would become established. Nothing might at first seem more fanciful than to expect an established schedule of damages adopted for the loss of a limb, or an eye, or other member. And yet the Pension Bureau, which deals with such cases by the hundred or thousand, has adopted such a schedule; so much for a right leg gone below the knee, another price for the whole leg, one price for the left eye and another for the right. Similarly it may be said that these mill damages in the last forty years in the New England states, when not notoriously excessive (they do not often err by being notoriously too small), have ranged from $50 to $100 or $125 per million gallons per day diverted, used

on one foot of fall. From which the value of a stated quantity of water diverted, used on any stated fall, may be judged between limits, or approximated, but taking into consideration all the attendant circumstances of the case in hand.

WATER RIGHTS.

BY RICHARD A. HALE, PRINCIPAL ASSISTANT ENGINEER, ESSEX COMPANY, LAWRENCE, MASS.

[*Read September 12, 1907.*]

The subject assigned to me to present this morning covers a very wide range of details, any one of which would easily occupy the allotted time. As the previous speaker has discussed the diversion subjects so thoroughly, I will confine my paper largely to the general subject on which the diversion matters depend.

In all diversion cases the main point to be first ascertained is the water rights of the company or individual, and what water and power can be depended upon before any diversion takes place. Water rights in general at any mill privilege comprise the use of the water for power and various manufacturing purposes, and when controlled by one individual or company no serious complications are liable to arise. When, however, the power is owned by several parties, questions may arise producing serious entanglements in the subdivision of the water, especially during the dry periods of flow. The early deeds relating to water rights were often vague and indefinite in relation to the subdivisions. A few examples will illustrate my meaning. The Essex Company, controlling the water power of the Merrimac River at Lawrence, leases the water in " mill powers." A mill power is the right to draw from the nearest canal or water course so much water as shall give a power equal to 30 cubic feet of water per second when the head and fall is 25 feet, to be drawn sixteen hours per day. As the height of water varies with change of seasons, the quantity of water is varied in proportion to the height, one foot being deducted from the height of the fall and also from that with which it is compared before computing the proportion between them; thus

for any fall the quantity of water to make a mill power is

$$\frac{750 - 30}{\text{Fall} - 1}.$$

The one foot is allowed for the loss of head in reaching and leaving the wheels. This definition of a mill power giving a constant power is explicit, and during the sixty-one years in which it has been in use, has admitted of but one interpretation and has never been questioned. The leases at Lowell, Holyoke, Turners Falls, and Bellows Falls are written on the same general lines, although in one locality the quantity of water is not varied in proportion to the fall as the fall changes. At Cohoes, N. Y., the "mill privilege," as it was called, was the right to draw from the canals of the company 100 square inches of water when the head and fall is 20 feet, that is, 3 feet head and 17 feet fall, to be drawn through a gap of cast iron or other metal having an aperture 2 inches deep and 50 inches in length, with the edge of the aperture not less than 1 inch in thickness; and in the same ratio for a head and fall greater or less than the above named.

Mr. J. B. Francis, the eminent hydraulic engineer, by agreement of the various mill owners, made experiments in 1859 with a head of 3 feet acting on the center of this form of orifice, and ascertained the quantity to be 5.9 cubic feet per second. Shortly after this, new proposals fixing 6 cubic feet per second on 20 feet fall were adopted for all future sales of water power.

Not all rights are so clearly defined or settled as those above mentioned, and a few examples are given of more obscure rights. One of the most prominent cases is the "Smith's Pond" water rights at Wolfboro, N. H., involving one dam at the outlet of the pond and two other dams just below on Smith River. Tradition says that disputes began in 1778 and have been waged at intervals ever since. However that may be, the quarrel began again in 1896, and at date of this writing matters are still before the court. The main questions were the rights in using the quantities of water from Smith's Pond at various times and the amounts that could be drawn throughout the year. With several different interested owners, and not very clearly defined water rights, the case has dragged along encumbered with legal questions, with no

immediate prospect of settlement. The writer and the late Mr. Freeman C. Coffin were associated with the case in the early days, but withdrew two years ago, feeling that little progress was being made towards settlement. Mr. Arthur T. Safford, consulting engineer at Lowell, Mr. H. D. Mears, and Mr. Lewis D. Thorpe have been called in at various times. One principal question which could have been settled if left to the engineers was the yield of the pond with storage, to see what could be drawn in various periods of the year. Definite observations were not taken in such a manner as to arrive at satisfactory results. The rights of the parties varied. One owner had the right to run when the pond was full, and others had rights to drive certain machinery. Estimates and measurements of the various water wheels were made with the quantity of water that was used and subdivisions made of the water. The hydraulic problems involved the amount of water that could be conveyed by certain sized penstocks, estimates of water necessary to drive wood-working machinery and grist mills, and the probable discharge of an old-fashioned tub wheel.

A more recent case, which involves various water rights in Hinsdale, N. H., may be of interest as being applicable in many places. A company was formed in 1839 in Hinsdale for the purpose of building a dam, canals, etc., and developing power for manufacturing purposes. Eight persons were interested in the scheme and owned the power in certain proportions measured by square inches. Various questions arising in regard to the quantities of water, in 1859 bulkheads of plank were placed at the entrances to their flumes, and orifices having the areas of their legal number of square inches were made in the bulkheads, at the proper distance below the surface of the water in the canal, by a legal decree of the court. The number of inches and head were very definitely stated, but thickness of the orifice plate was not mentioned. One party was entitled to the surplus in the river after all others had been supplied with their legal rights. In 1867 it was agreed by the manufacturers that the canal should be enlarged to carry an increased quantity of water, and to improve the general conditions of water power, and $1 500 was expended in this manner. It was also agreed that whatever increase was obtained should be divided *pro rata*, according to the number of

square inches owned by each party. At about this date the upper portions of bulkheads were removed and water was drawn over the top with no reference to orifices, and the amount of water drawn was limited by the capacity of the water wheels. In the year 1885 suit was brought, by parties owning the right to surplus, to compel the restoration of the upper portion of bulkheads, but nothing definite was accomplished. In 1905, owing to changes made by parties owning the surplus, a suit was brought against them by the remaining owners on the grounds of excessive use of water. The rights of all parties were to be determined. The writer had made some investigations for the parties entitled to the surplus, and the late Freeman C. Coffin was engaged by the other parties to the suit. As there were many hydraulic problems involved and engineering facts, that it seemed unnecessary to work up in duplicate, which would have to be ascertained in a suit in court, the writer suggested that the engineers should consult together and make a joint report. This was agreed upon by all parties, and the court appointed Freeman C. Coffin and the writer as engineering members, and Hon. J. H. Frink, counselor-at-law of Portsmouth, as the legal member of the commission. The commission were to hold hearings and make a report to the court as to the amount and the methods of drawing the water to which each was entitled. Several hearings were held, and testimony was given in regard to enlargement of canals and past use of water, and a report was made giving the amounts of water to which each was entitled under varying conditions of flow. The main problem was to determine the surplus previous to 1867, and what additional surplus was gained by enlarging the canal at that time, which was to be divided among the owners. All additional surplus belonged to the eighth party. The questions of the yield of the stream and capacity of the canal were considered and the fact that the parties had used the water for a long period (about twenty years), without remonstrance, was given weight. A system of measuring weirs was recommended and adopted by which each party should draw the amount to which it was entitled. As the parties were not entitled to quantities of water on an equal basis, but certain ones had priority over others, it was necessary to adapt the lengths and heights of the weirs to fit these conditions as far as possible.

Various adjustments were made after the weirs were placed in position. Another difficulty arose from the fact that the surface slope in the canal varied with varying quantities of water, necessitating heights of weir crests which were correct for one quantity and not strictly accurate for another. By experimenting with varying lengths and heights of weir, the quantity which each was entitled to draw was decided with a fair degree of approximation. For very small flows, tables of heights were given, showing when parties should cease drawing in the order of their decreed rights. Two of the rights have been combined, making one party less in the final division. In the later years no special efforts were made to maintain the rights of each owner, which, if maintained in a systematic manner, would have avoided the extensive investigation and adjustment. An objection to the use of measuring weirs occurs in the fact that they reduce the available head on the wheel. One other plan was proposed, that of attaching gages to the wheels and from the fall and openings regulating the quantities. This would require much more detail, and the owners preferred to lose the head during the low period of flow and have an automatic measurement rather than to require so much detail by the other method. During the period when water was abundant there was practically no head lost. Before the final report was made, both Mr. Coffin and Mr. Frink were removed by death and Mr. Lewis D. Thorpe, a partner of Mr. Coffin, who was familiar with the details, was appointed to fill the vacancy caused by Mr. Coffin's death. It is hoped by all parties that the matter is finally settled after long and tedious investigations.

Another case in the same locality occurred where a woolen mill and paper mill were on the same dam and the power was divided in the proportion of two thirds and one third of the flow of the river. As the paper mill used water for twenty-four hours, and the woolen mill for ten hours, various complications arose, and the matter was finally adjusted by measuring weirs dividing the flow of the stream proportionally. The storage capacity was very small above the dam and the vexed question of the difference in use of ten and twenty-four hours did not receive a weighty consideration.

The above examples have been stated somewhat in detail to

illustrate the importance of water rights being clearly defined when various parties are mutually interested, and also to illustrate the complications that may arise from neglecting such details.

As previously stated, in water diversion cases one of the main questions is to determine the amount of water which can be depended upon for power and the general flow of the stream. Most manufacturers have a general idea through their master mechanics of the amount of power at their mill privileges, but it is often stated in such a general way that it is not of value to an engineer as an accurate record. A system of keeping records of the flow of the stream at a small water power is not a complicated matter, and very valuable data may be collected without great expense. The general outline of the method is to use the water wheels as water meters and the overfall of the dam as a weir to measure the amount not drawn through the wheels. The Hydrographic Department of the United States Geological Survey has used this method, and various papers relating to the flow of streams and methods are familiar to all engineers engaged in hydraulic work. Messrs. R. E. Horton and H. K. Barrows of the Geological Survey have made special studies and reports on these general lines. A brief illustration is presented of the method as used at the Marland Mills, Andover, where measurements on the flow of the Shawsheen River were conducted for three years. The plant was a 14 set woolen mill with a breast wheel and a turbine situated on one side of the river and a second turbine on the opposite side of river. A separate flume led the water to each wheel. Gages were established in various locations, and the crest of the dam was fitted with a planed plank set at a uniform height (by a leveling instrument) to measure the water which wasted over the dam. All gages were set to a uniform datum plane and distributed as follows: The gages consisted of white pine boards 6 inches by 1 inch, painted white and marked in feet and tenths and half tenths and secured to posts attached to wall. One was set in the pond above the dam, which was used for obtaining the depth on crest; others were set in each forebay or flume above the wheel, to use in obtaining the fall on the wheels; another series were set in the raceway, to show the height of water after leaving the wheels. The difference between the two readings showed the fall on the

wheels. The total amount flowing in the river was then the sum of the following:

1. Amount wasting over dam.
2. Amount drawn by wheels.
3. Amount used for manufacturing purposes, such as dye house, boilers, etc.

1. The amount wasting over dam was deduced from the depths shown by the pond gage. Owing to the shape of the crest, the Lawrence dam formula applied to good advantage. An ideal apparatus would have been a self-recording gage to show a continuous record, but at this period, twenty-five years ago, such gages were not as available as at the present time. Readings were taken by the carpenter connected with the mill at intervals of two hours during the day, and the watchmen took a height in the evening, and one in the early morning, which were assumed to give a fair average of flows during the night. The readings were plotted with heights and times of observations on cross-section paper, and a line joining the observations showed the range above the dam. From the average line the amounts wasting during working hours and outside of working hours were determined. In this particular instance the working hours were from 6.30 A.M. to 12 M., and 1 P.M. to 6.30 P.M., stopping at noon Saturday. As additional to the convenience of this division, it indicated at a glance what water was available, if any, for an extra wheel at any portion of the year and the value of the pond for storage purposes. The ratio of the waste to the total flow and other interesting comparisons were deduced.

2. The amount of water drawn by turbines. In using the wheels as water meters, it is necessary to ascertain their discharge at various openings of the speed gates. The Holyoke tests form an excellent basis for these data. Changes in form of buckets and guides of wheels and outlet areas, variation in lengths and size of draft tubes often change the discharge, and it is desirable to measure the water as actually used by each wheel. If the wheel is running in connection with a steam engine, as is frequently the case, measurements may be made at various gate openings, thus determining the discharge, from which tables can be made. To determine the opening of the gate, a convenient method is an iron

or brass rod attached to the rack iron of the speed gate and of sufficient length to project through the wheel case where a scale divided in feet and tenths shows the amount of opening. Dial gages and pointers may be used if more convenient.

Measurements of water may be made by submerged floats or current meters in rectangular flumes or by weirs in the raceways. Diagrams of discharge show graphically the amounts discharged at various gate openings and falls acting on the wheels. At the Marland Mills the wheels were measured by submerged floats and weirs, and tables calculated for other falls than those observed. The heights of the speed gates were observed at intervals during forenoon and afternoon, and an average height used in determining the flow. The number of hours was noted that the wheels were run, as during the dry period it was necessary to shut off wheels a portion of the time. Wheels run at noon hour were recorded, and water used in the dye house and for scouring was measured at a separate outlet. Combining the quantities for the periods for which they were drawn gave the yield for twenty-four hours. It was necessary in measuring the quantities outside of working hours to ascertain the leakage from wheels and various pipes in dye house, etc., accurately, as this often formed a large percentage of the flow during a dry period. A similar system can be readily adapted to any mill privilege and records kept with but slight expense. The results in connection with rainfall on the area are of great value in the knowledge of the yield of the stream and its value for power. In these results the valuable data thus obtained show how the flow of the stream is distributed throughout the working hours and outside of working hours, and the amount available for actual use. The percentage of waste which cannot be utilized on account of lack of storage, sudden rains, and variable use by other parties on the upper portion of the stream is always a question of discussion in water division cases. The amount of 10 to 20 per cent. is often used in diversion cases and is a reasonable amount. The storage capacity is a large factor in this matter, and in Lawrence, on the Merrimac River, with considerable storage there has recently been a period of a month when no water was running over the dam. On a smaller stream the range of percentages of 10 to 20 per cent. would be reasonable.

It is often possible to place a gage in a stream unaffected by dams below, which should give a correct index of the quantity of water passing. The quantity of water must be measured with various readings of the gage and a diagram constructed showing the actual quantity flowing at various heights. For the flow of twenty-four hours a continuous record of the gage must be taken and the average height for that period taken. If the water power is used chiefly during the ten working hours, a reading of gage taken during period of steady flow may be used after ascertaining its relation to the average for twenty-four hours.

The records of a large water power, as the Merrimac River at Lawrence, are kept in the same general methods, but necessitate more details. Flashboards on the dam are kept in good condition and levels are taken on the crest of the boards at intervals so that from the depth flowing over the boards the quantity of water may be computed. Outside of working hours the head gate openings furnish a means of measurement in the canals and various leakages through wheels and waste gates, etc., are measured and combined in the twenty-four-hour flow. The results are of value to show what extra water may be depended upon if surplus is desired. A gage is located in the river near the lower end of canal and readings of this gage indicate the quantity of water flowing as ascertained by previous computation. During the period of ice floating in the river when the flashboards are broken and pins bent over, it is necessary to use this gage in ascertaining the quantities. These periods are quite infrequent and in general the more exact methods are used.

In the customary method of ascertaining the yield of a stream, the average of the driest months is taken for a series of years, then the next driest, and so on. This is preferable to the calendar months where a wet January of one year would be averaged with a dry January of another year and present misleading figures. After a manufacturer has collected his data showing the average yield per month, the power can be computed and the average power for the year ascertained. Another table can be arranged showing the conditions after a portion of the water is diverted, and the difference shows the average loss for year. In computing the power month by month it will be borne in mind that wheels are

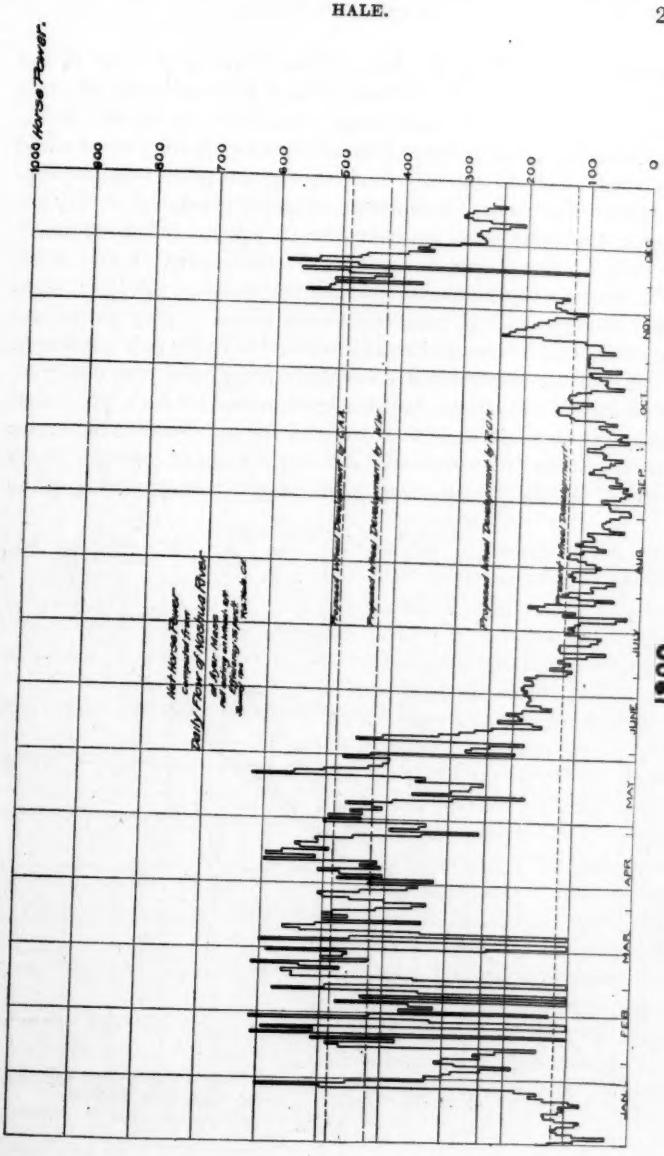

1000 Horse Power.
900
800
700
600
500
400
300
200
100
0
JAN.
FEB.
MAR.
APR.
MAY.
JUNE.
JULY.
AUG.
SEP.
OCT.
NOV.
DEC.
1900

FIG. 1.

generally installed to use the capacity of the stream up to the eighth month. There are periods of large flows and reduced heads when a wheel may be used supplementary to the regular power, but whether it is a profitable investment to run four months and to remain idle during the remaining eight months must be considered. In the use of turbines the efficiency is reduced on very low flows; the speed gates are open a small amount and the efficiency is poor. After diversion occurs, the smaller quantity that is left will be used with less efficiency on the turbines and this loss is often very appreciable. If great difference exists, it may necessitate new wheels of other capacities to be adapted to the new conditions.

In some diversion cases where daily flows have been observed, a diagram showing the available horse-power for each day before and after diversion and the capacity of the water wheels illustrates the actual condition without involving a series of averages which smooth out the irregularities. An example is shown in Fig. 1, the

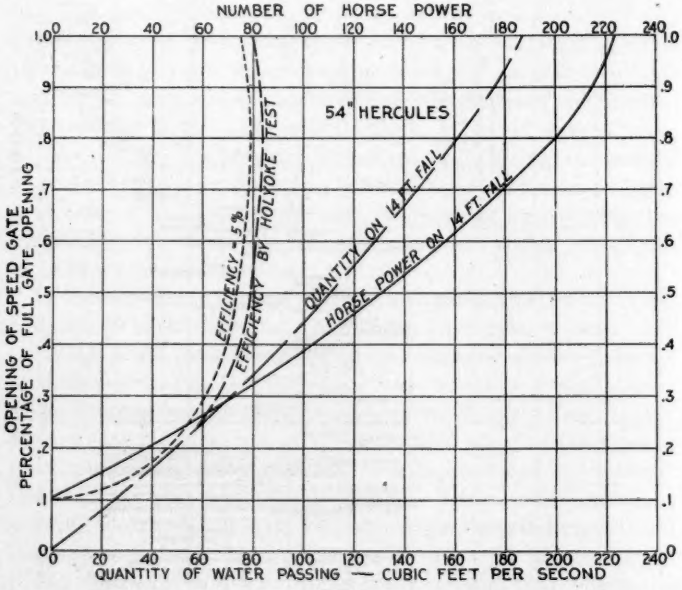

NUMBER OF HORSE POWER
0 20 40 60 80 100 120 140 160 180 200 220 240
1.0 .9 .8 .7 .6 .5 .4 .3 .2 .1 0
OPENING OF SPEED GATE
PERCENTAGE OF FULL GATE OPENING
54" HERCULES
EFFICIENCY - 5%
EFFICIENCY BY HOLYOKE TEST
QUANTITY ON 14 FT. FALL
HORSE POWER ON 14 FT. FALL
QUANTITY OF WATER PASSING — CUBIC FEET PER SECOND

FIG. 2.

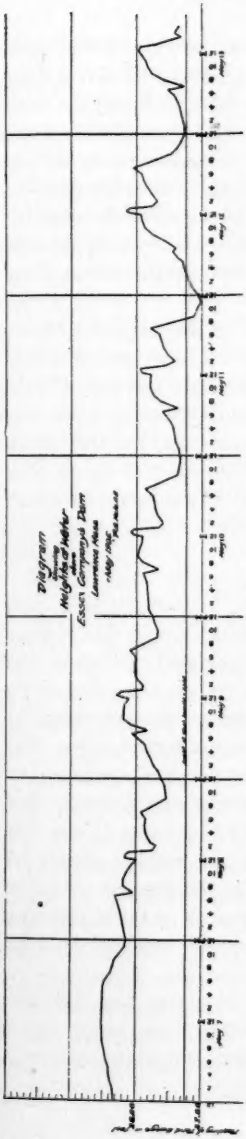


FIG. 3.

diagram of daily horse-power at Nashoba Company on Nashua River, which shows the variations in horse-power which exist in the variable flow of the stream. The necessity of installing a steam plant to supplement the small amount of power obtained during the dry months is shown by the large area between the various wheel developments and the actual power. During sudden storms and rises of the river, water is lost by wasting as indicated by sudden rising in the spring and fall. The lines shown for wheel development were used by various engineers in the diversion case.

Diagrams for obtaining graphically the horse-power from the wheels, percentage of efficiency, etc., with the quantities of water discharged at various gate openings, are useful in presenting the cases, and an example is shown in Fig. 2. In Fig. 3, the diagram of height of pond above dam at Lawrence is plotted from hourly observations and the range of heights of water shown by the irregular black line. The horizontal line shows the crest of flashboards. An average height is taken for intervals of one or more hours, depending on the variation of heights. The quantity of water is computed from the J. B. Francis weir formula, or, if the flashboards are gone, the Lawrence dam formula is used.

The financial damage from the diversion of the water varies with the condition of each case and no fixed general rule can apply. With combined steam and water-power plants and varying conditions in the use of steam and engines, a special investigation must apply in each case. The general expenses connected with the engines and maintenance are well known and can be ascertained from well-kept records. The general expenses of water-power maintenance vary in each case. Repairs on dam and canals, care in winter for anchor ice, snow storms, etc., often increase the expenses materially.

I have preferred to deal with this branch of the subject without taking up the subject of financial damage due to diversion which would extend the paper to an unreasonable length and has already been ably presented. It should be stated, however, that the manufacturer should receive a fair compensation for the water diverted and the expenses of running by steam and water considered and a sufficient sum be paid to cover the annual loss which exists.

DISCUSSION.

MR. H. K. BARROWS.* Mr. President, I have little to say, except to express my general interest in the subject. Mr. Main's paper interested me in the matter of wheel capacity; that is, the amount of horse-power or the number of wheels that should be installed in a new plant. Some data on that subject would be of interest, showing how installations vary for different uses. For instance, in the case of pulp and paper manufacture, installations are often made for two or three times the amount of water expected during eight or nine months of the year, the idea being to use this excess installation in grinding the pulp when there is plenty of water, and then later on using the pulp in the process of paper manufacture. Perhaps Mr. Main could give us a table showing about what he considers to be the proper wheel capacity for the different types of installations.

The matter of keeping a record of flow is, of course, one that has interested me greatly, and frequently it can be done, as Mr. Hale has said, with little expense to the mill owners, furnishing informa-

* Civil Engineer, Boston, Mass.

tion of great value. It is too often the case that when this information is very much needed, it is not available, in questions of water rights or in improving a plant, as these records must be obtained over a series of at least a few years to be of conclusive value.

In the adjustment of the flow of water and the consideration of water rights there is a further division of the subject that has not been mentioned, *viz.*, that of securing and operating additional storage and apportioning the cost of this among different mill owners upon the river in question. The common situation, on such of our New England streams as furnish good natural facilities for storing water, has been that some one of the power users on the river has acquired control of this storage and operates it; usually, however, to the benefit of others on the river, and with no cost to these others. The time is approaching, however, when storage of water for power use during the low-water season will be attempted on a larger scale; and to make this profitable, the expenses of construction and maintenance must be borne by all who are benefited.

The necessity of careful and systematic regulation of flow from storage reservoirs has in many cases not been realized. Thus in the State of Maine the three large power streams, the Kennebec, Penobscot, and Androscoggin, are naturally equipped with lake systems, well up in the head-waters, which furnish admirable facilities for storing water. The development of this storage has, however, been slow, and, until within a few years, almost entirely for purposes of log driving. The Kennebec River is especially well equipped with lakes and ponds, comprising Moosehead Lake with 115 square miles of water surface, and the numerous other large lakes of the tributary Moose, Roach, and Dead rivers. The regulation of Moosehead Lake, at present the only one of these lakes used to store water for power purposes, is in the hands of the Kennebec Water Power Company, which company is made up of the principal owners and operators along the main river.

Log driving and lumbering interests in this river are represented by the Kennebec Log Driving Association. As these two companies are made up largely of the same parties, the present control of the lake storage is entirely harmonious. Log driving, however,

requires a large amount of water, and at times when it should be stored for power uses. No systematic regulation of flow from Moosehead Lake is maintained and much water is wasted, especially during the log-driving season. The speaker has shown in the case of Kennebec River * at Waterville, where some of the large power interests are situated, that during the period of 1893–1906 a low water flow, never less than about 2 500 second feet (depending upon what assumptions are made for water used in log driving), could have been secured, by a proper control of storage facilities at *existing* dams. As a matter of fact, a mean monthly flow as low as 921 second feet was reached at Waterville during February, 1904, showing how little attempt has been made to regulate flow on a river where large power interests are already situated.

The development and control of water power is now being considered by several of the states. New York, for example, under the "Fuller Bill," has recently passed an act "authorizing and directing the state water supply commission to devise plans for the progressive development of the water powers of the state, for the public use, under state ownership and control"; Pennsylvania and New Jersey have also enacted laws relating to state control of water resources. The water-power project of to-day is coming to be more and more one involving storage, and some interesting questions of water rights and assessments will be brought about by state control, in the apportioning of betterments occasioned by storage, among existing water powers.

It seems reasonable to predict that our rivers in the future will be "operated" by means of storage reservoirs, as far as can be done with economy, — conserving the spring and fall floods to provide water for power users during the periods of drought, and incidentally preventing disastrous floods. Whether state or national control will be needed to properly carry this out and develop our water resources as they should be, is a question of great interest and importance.

MR. LEONARD METCALF.† I have listened to these papers with much interest, and one or two questions have occurred to me;

* See Water Supply and Irrigation Paper No. 198, U. S. Geological Survey.
† Consulting Engineer, Boston, Mass.

one particularly along the line raised by Mr. Barrows, — a question which I thought of asking Mr. Main and Mr. Hale, — whether they chance to know of any cases in which settlement has been arrived at through the payment to the mill owners " in kind," that is, by the development of the storage facilities of the drainage area, other than the mill ponds would supply, by joint action of the interested parties or by one or the other of those parties.

It was suggested to me by a case in which Mr. King is interested at the present time, in which I made some figures which tended to show that the storage developed upon the head waters of the stream actually benefited the owners who were suing for the diversion of water. Yet the owners succeeded in getting a small award. The litigation isn't over yet, and we have hopes at least that the award will be very small. It certainly opens a very interesting field of thought, and it seems to me that in some of these water diversion cases it is the natural and the most equitable solution of the problem. Whether we can get the lawyers and the courts to take that view of it or not remains to be seen.

I also want to ask Mr. Hale one question about the Nashoba privilege development. I understand that since the litigation the dam at this privilege has been rebuilt, and that power is being developed for a certain traction company. It might be interesting to know to what extent they actually do develop the privilege,— in other words, what wheel capacity has been installed at that point.

Mr. Hale. I do not know just what capacity of wheels they put in, but I understood that they spent $100 000 in the new dam, flumes, penstock, and so forth, there. It seemed, in general, a very large amount per horse-power on such a low fall as existed there, and I have been intending to determine the exact amount at a later date. I ought to have added, perhaps, in the course of my remarks, that Mr. Metcalf was one of the commissioners in the Nashoba case that was adjudicated. I think we should be very glad to hear any additional points in regard to that.

Mr. Metcalf. Mr. Chairman, perhaps there is one thing I might say in regard to that case. I think commissioners are usually rather wary about discussing cases which have been decided by them and the elements which weighed in the decision. I think it

is fair to say of this case, however, that the low head at this privilege was a factor in the decision.

The head was 8 feet, and at times of flood and in the high water season that head is cut down to about 6 feet, as I now recollect the figures. Of course, under these low heads the question of the regulation of the speed of wheels is an important factor in the proper operation of the generator, if electric power is developed. I should say that the regulation of the speed is much more difficult, and the variation in the speed becomes more serious in the operation of the privilege, and that fact weighed in the award which was finally made.

The valuations in this case on the part of the several experts ran from about $10 000 to $130 000, — that is the estimate of the damage due to this partial diversion,— the engineers for the Commonwealth giving estimates of from $10 000 to $15 000, and those for the company of from about $85 000 to about $120 000 or $130 000, as I remember the figures. The award was $25 000.

Mr. Hale. I might add a word in regard to Mr. Barrows' statement about storage. Some two years ago that matter of storage was taken up in New York, with reference to storage basins on the Batten Kill and other rivers, with the possibility of ascertaining if the floods at Troy and at other places could not be reduced by arranging such storage.

I attended a hearing before a commission at Albany, and it looked at that time as though the prospect was very good for something being accomplished. The commission was inclined to take the matter up, investigate it, and build some storage basins, and would coöperate with the mill owners, to the extent that the state would pay a certain percentage. I don't recall now whether it was 40 per cent. or 50 per cent., but it was something like that. The mill owners would pay in proportion to their power — or fall. They had a few hearings, and I think the matter was then declared unconstitutional, in regard to development along that line, — that the state couldn't go into it,— and the matter was dropped.

I understand that since that period they have been taking it up again. The mill owners on the Batten Kill are now agitating the question of building storage basins. I have been formulating an arrangement by which a company might be formed, so that

an agreement might be made by the various parties to do something and bear proportionally the expense. Whether it will come to anything or not, I don't know.

MR. METCALF. Do you chance to know, Mr. Hale, whether it is a fact or not (I believe it is a fact) that on the Blackstone River —or on one of the streams flowing into it — that very thing has been done by the Draper Company or some other mill owners?

MR. HALE. Storage?

MR. METCALF. Yes; by the construction of the Echo Lake dam.

MR. HALE. I don't happen to know of that.

MR. METCALF. I think that it was the case that the mill owners coöperated and built this dam for the storage of the water, and that the cost was met by the various mill owners. Whether they all entered into agreement or not I do not know, nor do I know the expense involved in the work.

MR. HALE. The question on the Batten Kill in regard to the mill owners was in what way they should be assessed. The natural way would be in proportion to the fall, although in case of some of the falls which were not fully developed, or were undeveloped, the parties felt as though they shouldn't pay a proportional amount. That would be something to be agreed upon among them.

MR. W. C. HAWLEY.* Mr. President, as a matter of interest along this line I might say that when the city of Troy was considering the Batten Kill supply, some twelve years ago, it was found that in order to get the water to the distributing reservoir a ridge had to be crossed, and that there would be 10 000 000 gallons per day with an available head of something like 200 feet from the top of this ridge to the distributing reservoir. It was proposed then to develop this power and supply electric power to the various mills whose horse-power had been reduced by the diversion of this water. The scheme was worked up to a point where we considered the legal end of it, and it was decided that it couldn't be done under the existing laws of the state of New York, and for that reason was given up.

It would have more than replaced all of the power which was

* General Superintendent, Pennsylvania Water Co., Wilkinsburg, Pa.

taken from the mills, and would have given the city of Troy considerable power available for street lighting, and so forth.

MR. MAIN. In answer to Mr. Metcalf's question I would say that during the time the Worcester cases were under consideration —the Kettle Brook cases—it was suggested that that very thing be worked out and presented in evidence, and Mr. Freeman C. Coffin was employed. He did a considerable amount of work along those lines, but counsel for the city decided that it wasn't proper to put it in, so it was dropped. I understood at that time that in England it was lawful to pay in kind,— to build a compensating reservoir and to supply as much water as had been taken away in that way, but that it couldn't be done in the state of Massachusetts.

MR. KENNETH ALLEN.* Mr. President, several years ago projects for an additional water supply for the city of Norwich, Conn., were taken up. I am very sorry that Mr. Chandler is not here to read his paper, because I thought, being fully acquainted with the circumstances, he would probably touch on the question of compensation in kind in that connection.

The firm to which I belonged at that time made an investigation and recommended compensation to the mill owners below the proposed reservoir by paying in kind. There were a number of mill properties below the watershed that would be affected, but we showed to our own satisfaction — if not to that of the mill owners — that they would be bettered by the improvement.

As a matter of fact, this proposed supply was about 7 000 000 gallons a day, while with the old supply they were getting about 2 500 000, and we considered that, with the natural growth of the town, the city would be justified in expending the amount of money necessary to provide the larger supply. As a matter of fact their bond issue, I understand, was limited to a certain amount, which wouldn't quite pay for this, so that the works were never built.

I was very much in hopes the matter would come to such a point that it would be shown whether this could be put through. I understand the mill owners made a claim for damages of about $100 000. That added to the cost of the works would probably have been prohibitive.

* Division Engineer, Baltimore Sewerage Commission.

There is one question I should like to ask, and that is whether there has ever been any consideration of damage to a lower water right on account of *pondage*, this being in the nature of a damage rather than a compensation; that is, pondage, rendering uncertain the supply of water to a lower mill, would naturally act as a detriment rather than an advantage in operating the said mill, for which damages might be demanded.

MR. MAIN. I was going to add that too much weight could not be placed upon the use of very definite terms in the division or appropriation of water rights to determine the amount of water to be used by different parties upon the same privilege.

Two very interesting cases have recently come to my notice, one of which I have worked out and the other one I have not been able to work out yet.

A short time ago I was called upon to see if a certain party was using more water than properly belonged to him. The terms of the deed were something like this:

It was dated in 1872. It stated that the mill connected with this privilege had the right to use as much water as would be required to run 200 cotton looms, and the complement of other machinery, on a wheel not less efficient than a good breast wheel.

Fortunately, the shafting had not been removed from the mill and I was able to determine from that and from a workman who had been in the mill some forty years, the width of the looms used and the kind of goods produced. From this, I determined how much machinery was required, and how much power was required to run it, and after determining the efficiency of a good breast wheel in 1872, I was able to determine the amount of water to which the privilege had a right.

In the other case, the deed was written in 1861; the party had a right to use as much water as would be required for a 10-set woolen mill for power and manufacturing purposes.

To determine the amount of water, it was necessary to ascertain the greatest width of card used in 1861 and to work out the organization of a 10-set woolen mill, based upon such width of card, and to determine the maximum amount of power required for a 10-set woolen mill and the amount of water required for power and for manufacturing purposes for the same.

Deeds written as indicated above are very indefinite and when written to-day should designate the amount of water in cubic feet per second to be drawn, so that there will be no question about the amount.

CHAIRMAN KING. Mr. Metcalf said that the statute required that the dam be built above the privilege, so there is no question about providing for the storage. The question is of the offset for damage. Another question arose in that case — perhaps Mr. Metcalf looked into it — where different parties were taking water from the stream, one below the other, of course, where they formerly all drew water in the daytime. Then, by a change, the water went into the hands of an electric light company, and they use the water in the night. Whether there is anything to be said upon that subject, — perhaps Mr. Metcalf looked into that question.

MR. METCALF. I don't know, Mr. Chairman, that I have very much to add on that matter. It seems to me the question of pondage — the same question to which Mr. Allen has alluded — is a very vexed one, — one on which we haven't had very definite decisions, beyond the fact that the courts have ruled that reasonable use on the stream should be considered. Just what reasonable use of the waters of a stream, or just what that term means, is, perhaps, a little vague. In the case to which Mr. King refers, I stated in my report:

"It is evident from the small flow of this stream during midsummer, that there are times when substantially the entire twenty-four-hour discharge may be impounded within the mill pond of the electric-light plant and utilized during the evening hours of peak load at the plant. Under these circumstances, since the mill pond of the next privilege is probably considerably smaller than this mill pond, and hence would not be able to store the entire quantity let down at night by the electric-light plant, and thus make this water available for operating purposes upon the following day, — the court would probably construe such storing of the entire quantity of water flowing in the stream and the use of it during a few hours in the evening when other manufacturers' plants were shut down, as unreasonable. Were this view taken, the town might be enjoined from the use of its mill pond for its

own best advantage, and the power which it might derive from the stream for its own use might thus be considerably reduced. If, on the other hand, the stream flow during the day were sufficient to take care of the needs of the mills, or if these mills had mill ponds of sufficient capacity to enable them to store during the dry season the entire twenty-four-hour flow of the stream, the town could doubtless avail itself of its mill pondage to the most advantageous limit."

I assume that where the character of the use has changed materially,— as in the case of an electric-light plant which has been established on a stream, and which wishes to use the water during hours only when the mills are virtually closed, as against the former use by a mill which operated twenty-four hours out of the day, — that the court would not hold that the newcomers would be entitled to so radically modify or change the regimen of the river for their own benefit as to seriously affect the operation of the privileges below them.

The question depends upon the size of the mill ponds above the privileges, as well as upon the quantity of water which is flowing in the stream. No court, I assume, would permit an electric-lighting company, for instance, to hold up all of the water during the daytime, to the disadvantage of the mill owners below who wanted to use it throughout the day, unless the mill owners below had mill ponds, which would make it possible for them to store the water, or the major portion of it, which was let down in a few hours during the night by the electric-lighting company.

It occurs to me to say just one word further, along the line to which Mr. Hale and Mr. Main just alluded, — the exact definition of terms. Mr. Main has just referred to the term " head." We recently had an interesting case in Maine, in which the word "head" was a matter of dispute. In this case a privilege had been sold, with the understanding that 17 feet of head were to be had at the privilege at a certain time, for the use of log drivers. The question then came as to how that head should be measured. It was the head from the bottom of the dam, was it not, Mr. Hale?

MR. HALE. Yes, sir.

MR. METCALF. The experts on one side contended that, according to usage on lumber-driving streams, head was measured

at dams built for storing water for log sluicing and driving purposes from the sill of the dam or bottom of the waste gate, to the surface of the water above the dam, unless there was back water at the dam, and that the bottom of the dam was at this point, the structure below this point being in the nature of a sub-foundation. The experts for the other side contended that the bottom of the dam was the bottom of the lowest log in the structure, and they actually sent a diver down to get the elevation of the underside of the bottom log in the dam.

Of course, counsel for the plaintiffs took the view that, under the latter interpretation, out of 17 feet of head they would get something like 12 or 15 feet of mud, instead of water. It certainly was not water, nor was it available or convertible into power.

MR. J. H. COOK.* I have listened with a great deal of interest to the remarks of the various gentlemen, and some of the things which were referred to had considerable interest for me. I suppose I can't talk of these things in their proper order, but I noticed that some one spoke — Mr. Barrows, I believe — about state regulation of water supplies, or control by the state of water supplies.

In the state of New Jersey at present, under a statute passed last winter, there is a commission appointed which claims to exercise control over all the waters of the state, and expects, according to the ideas of the people of the state, to build reservoirs and perhaps sell water for the supply of various towns in the state. Whether the state may sell water or not for that purpose of course has not been determined by any suit as yet.

The commissioners also intend, according to the terms of the bill, to cause all parties that divert water from the streams to pay to the state a certain amount per million gallons for water so diverted. The state, in fact, believes, or the legislature believes, that the state has absolute control over the water of the state.

I have heard, too, some of the speakers speak about compensating reservoirs. I know of a case — I did not suppose that they were very uncommon — in the state of New York. The Consolidated Water Company of Utica, N. Y., maintains a compensating reservoir on the upper waters of the West Canada Creek, and through agreement with the mill owners below, said company

* Hydraulic Engineer, Paterson, N. J.

passes out from this reservoir (which is on the upper Black Creek,—a tributary of West Canada Creek) the natural flow of the streams which flow into this reservoir, plus the amount the water company diverts at Hinckley, a point some miles down the river. They have only operated the thing about a year, and there has been some little friction already.

Somebody spoke about compensation in kind, and it made me think of a case in New Jersey, which perhaps may be familiar to some of the gentlemen now present. The water of the Pequannock River above Charlotteburg was taken by the city of Newark, which contracted with the East Jersey Water Company to build works for a water supply for Newark. On this river were some small streams upon which dams and reservoirs were built. After this work was completed, that is, after the storage reservoirs were built, the quantity of water that passed down the river into the intake reservoir was practically constant, changing the flow of the river, which had formerly been in the driest times two or three millions of gallons or less daily, and a very large quantity in times of freshet. A mill owner sued the company that built these works because he said they interfered with the natural flow of the stream, and the mill owner recovered damages; and presently, a few years afterwards, he brought another suit for interference with the flow of the stream since the time he recovered before, and again recovered damages. Then the water company got sick of that game and bought the property, which it was claimed was injured, although it appeared to some persons to have been benefited.

Mr. E. L. Grimes.* Mr. President, I have been very much interested in the discussion before the meeting, as we are at present trying out some of these cases in Troy, N. Y., and especially the one that has been referred to. One of the important points with us is in regard to compensation for the diversion of part of the water from the stream. A question which I think Mr. Main did not touch upon in regard to substituting a steam plant for the power diverted, is in regard to its location, distance from the railroad, or convenience in getting to the point. Now, the cost of substituting steam at a point that is very difficult to

* Chief Engineer, Troy, N. Y., Water Works.

get at would be much different from that at a point easily accessible and would, it seems to me, make quite a difference in the question.

Another question that is brought up is in regard to storage: A large mill owner upon the stream below our diverting dam has, above our diverting dam, quite a large storage reservoir. In certain seasons of the year, if he happens to be short of water, he lets this storage reservoir run down, and of course it benefits the parties between the storage reservoir and the owner's mill.

The point to decide is, What rights to the use of these stored waters have the mill owners who do not own the storage reservoir, or who depend entirely upon the flow as it is let down by the party who owns the storage reservoir? I understand that the mills intermediate do not pay any part of the maintenance of the storage reservoir, and I suppose they could not force the party to maintain the dam there or let the water down at certain times. Another question is, What value is that storage reservoir to the parties who do not own it?

We have also another system on which the riparian rights have been settled. It seems to me it would be interesting to know, or to have tabulated in some form which would be convenient for comparison, the awards of the damages in similar cases; and, in view of that, I have tabulated the cases relating to water powers that have been settled.

TABLE SHOWING AWARDS MADE IN 1903 FOR DAMAGE TO WATER POWERS BELOW DAM OF TOMHANNOCK RESERVOIR, TROY (N. Y.) WATER WORKS.
Drainage area above reservoir dam, 67 square miles.

	Remarks.	Total Award.	Award per Sq. Mile per Foot Fall.
About 1 mile below dam,	Old flax mill not used for several years, also old saw mill. Total fall, 18 ft.	$4 500.00	$3.75
About 1 mile below dam,	Farm area not given. Grist mill rather old. Total fall, 18 ft.	12 000.00	10.00
About 2 miles below dam,	Farms and water power undeveloped. Total fall, 150 ft.	22 000.00	2.20

	Remarks.	Total Award.	Award per Sq. Mile per Foot Fall.
About 3 miles below dam,	Undeveloped power and farm of 240 acres; 180 acres affected. Total fall, 40 ft.	16 000.00	5.97
		$54 500.00	$3.55

MR. HALE. Mr. President, in regard to the use of the ten- and twenty-four-hour power, there is considerable attention being paid to that now, I think, by the various companies. When parties were attempting this year to obtain a charter for a dam at Reeds Ferry on the Merrimac River, the counsel for the Amoskeag Manufacturing Company was very insistent that there should be included in the charter the clause that no interference should be asked for in regard to the customary hours of running the mills at Manchester, or at any locality on the river above this point, as far as Lake Winnepesaukee.

They felt as though if this dam was to supply power twenty-four hours or ten hours, or whatever it might be, they might have some rights to insist on the natural flow of the stream, and they didn't know what might arise. These manufacturers wanted to protect themselves in that way, so they asked to have that clause put into the charter, which was agreed upon, as the probability of interfering with the mills above would be very remote.

I think in regard to the use of ten-hour and 24-hour power there is a case of Mr. Whitney at Winchendon in which Mr. Main and Mr. Coffin were consulted. I don't know how that was decided by the courts, but I think Mr. Main can tell us about that.

MR. MAIN. I have the result of that case in mind. Mr. Whitney owned a large reservoir, and formerly had two water wheels, — one for his cotton mill and one for his machine shop,— and ran them both during the daytime. Several years ago the cotton mill ceased running, and the wheel in that mill stopped, and he used only the wheel in the shop. A few years ago he conceived the idea of using the wheel in the cotton mill for electric-lighting purposes, to light the town, and ran that during the night. He had a large reservoir to control the water and the owners below

him had very small ones and whatever water went through the cotton mill wheel at night got past their dams. They brought suit to make him stop using the water at night, and to require him to use it, they said, in the customary and ordinary manner, which was ten or twelve hours a day. Mr. Coffin and I found that approximately the same amount of water was used in the twelve hours of daytime as during the twelve hours of night-time, or about as the natural flow of the stream. Every one connected with the case for the mill owner thought he had a very good case, that the mill owners below could not make it necessary for him to use his dam and pond for their benefit, storing the night waters so that they could use it all in the daytime. We felt if he wanted to shut down his shop he could do so, and if he did the water would flow over his dam uniformly twenty-four hours a day.

The case was tried before a master, and the master found that Mr. Whitney must cease to use the water in the night, and use it only in the daytime. Mr. Whitney paid no attention to the finding of the master, and kept on running day and night. The court overruled the finding of the master, and found that Mr. Whitney had the right to use the water twenty-four hours in the day, provided that he used it as it came down to him and about as the natural flow of the stream. So that it turned out finally as we thought it ought to and as common sense would indicate, and everybody was happy except the mill owners below.

MR. A. A. REIMER.* Mr. Chairman, that brings to my mind the question whether underground waters have been involved in any of these suits.

CHAIRMAN KING. Can any one give us any information on this subject? Wasn't that suggested in the Newburyport case, Mr. Forbes?

MR. FORBES.. Mr. President, I don't know as I can answer this question just at this point. The matter of a ground water supply and the proportion it bears or the effect it has in regulating the flow of a stream, and particularly the flow during a dry season, is of course a very important one. It perhaps becomes less evident upon the larger streams; that is, the total effect is not so great; but where a small drainage area is considered the result

*Superintendent of Water Works, East Orange, N. J.

may be very noticeable, due perhaps to the fact that we do not know the extent of the drainage area, from a ground water point of view, with the accuracy with which we know the surface drainage area. So that unquestionably in many cases on small drainage basins the tributary ground area may be very much larger, thus accounting for the unusually high flow per square mile during the dry season. Possibly that is not just along the line that the speaker asked his question, but that may explain it somewhat.

MR. GRIMES. Perhaps it would be of interest to know about a little experience we had in a claim of this kind. A farmer put in a claim for diversion of the water, on the ground that it prevented percolation of the water through his land. His claim was for $5 000. In investigating the matter we found that he had something over five miles of tile drain laid to keep his land dry.

CHAIRMAN KING. Will Mr. E. H. Foster, of New York, add something to this discussion?

MR. FOSTER. I hadn't intended to say anything on this subject, Mr. President, but I have taken down a few notes on points that interested me in the papers that have just been read. One thing that impresses me about these cases is the very wide diversion between the estimate of value of the power as made by the mill owner and the value placed upon it by the prospective purchaser. About 20 to 1 seems to be the usual ratio. I have a case in mind where it was just about in that proportion, and I think Mr. Metcalf mentioned another. Much depends upon the circumstances surrounding the cases, the condition of plants, and so forth. An owner usually is able to see ahead that his water power is going to be condemned, and he lets his plant run down for three or four years, oftentimes until it is practically valueless at the time proceedings are instituted for making an appraisal, and it is very hard to get at the conditions as they existed at the time when the owner really first began to let his plant run down.

It seems to me that this general subject is of sufficient importance to the members of this Association to consider the appointment of a committee. Nearly all of these cases are between municipalities and mill owners. We represent largely municipalities. The mill owners are largely represented by members

of the National Cotton Manufacturers' Association. The membership of these two associations is chiefly drawn from the same part of the country. Hence, the members are naturally familiar with the same problems from their respective viewpoints. Furthermore, the abundance of water power and the tendency toward manufacturing, has naturally led to a great many disputes on this subject in New England — probably more up to the present time than in any other part of this country.

Why would it not be a good plan to have appointed a committee to approach the cotton manufacturers, and intimate that they should appoint a committee, and have these committees act jointly to get up a set of rules or recommendations for estimating the value of water power diverted or appropriated for various purposes, and generally to embody the ideas presented in various papers before this Association, before the American Society of Mechanical Engineers and the American Society of Civil Engineers the valuable contributions by the author of the paper under discussion, the works of Frizell and various other writers on the subject, and boil it all down to a simple set of rules, which could be applied to a great many cases?

These cases are usually brought before a court and the court appoints a commission, which is generally a lay commission, and they hear the testimony. The result is a great waste of time and expense, which is not at all justified by the amount involved.

I really believe it would be conferring a benefit not only upon the mill owners,— the small mill owners especially,— but also upon municipalities that contemplate changes in their water system, to have some definite rules which could be regarded as more or less authoritative, and with this object in view, Mr. Chairman, I offer the following motion:

"That a committee be appointed by the Chair, to approach the National Cotton Manufacturers' Association, and invite them to appoint a committee, these committees to act as a joint committee to draw up a set of rules to govern the estimation of damages to water privileges by diversion."

MR. CHARLES W. SHERMAN.* Mr. Chariman, it strikes me off-hand, without opportunity to give much consideration to the

* Civil Engineer, with Metcalf & Eddy, Boston, Mass.

matter, that this committee would have a very difficult problem, to say the least, and might find it impossible to get any coöperation from the Cotton Manufacturers' Association, in which case they would be thrown back on us with nothing done.

I am inclined to offer, as an amendment to Mr. Foster's motion, that the committee be appointed as he suggests, but instead of asking the cotton manufacturers to name this other committee to act with them, that our committee be appointed to consider the practicability of such a joint committee, and the possibility of its obtaining results that would be of value, and, if they see fit, to confer with the officers of the Cotton Manufacturers' Association as to their ideas and their practicability and possibility. It is hard to put that amendment in form without rewriting it.

CHAIRMAN KING. It would be a substitute motion.

MR. METCALF. Mr. President, if I might make a suggestion, I should like to ask Mr. Sherman if he wouldn't include in his motion that this committee should collect data relating to awards for diversion of water and water power. It seems to me that the most valuable work this committee can do, or will be likely to accomplish, will be to accumulate specific data regarding awards in such cases. There have been quite a number of suits, on different streams, growing out of diversion, and the members of this Association, I think, can bring the data relating to awards together and put them into the hands of the committee, if the committee had power to accumulate them.

I question very seriously whether we will be able to get the coöperation of the Cotton Manufacturers' Association, and even if we do, whether it will be very effective. Of course the courts will finally have to pass upon the question of proper damages, and it seems to me it is a pretty big task to place upon any such committee, whereas data could be accumulated comparatively easily.

CHAIRMAN KING. Perhaps it is not quite in order for us to dispose of that before it is amended in the motion. Is there anything further to be said in relation to the appointment of this committee, or any suggestions? If anybody has any suggestion to make it is a good time now to mention it.

Mr. Sherman offers the following substitute for Mr. Foster's motion:

"That a committee of five be appointed by the President to collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers' Association, or other organization of mill owners, leading to the formulating of standard rules and methods of computing or assessing damages for the diversion of water."

Does Mr. Foster accept this substitution?

MR. FOSTER. I accept that.

CHAIRMAN KING. Then, as Mr. Foster accepts this, this motion is now before you. Is there anything to be said on the motion?

The motion was put to vote and carried.

CHAIRMAN KING. It is a vote and the motion is adopted.

THE SPRINGFIELD WATER WORKS.

BY ELBERT E. LOCHRIDGE, CHIEF ENGINEER, SPRINGFIELD WATER WORKS, SPRINGFIELD, MASS.

[*Presented September 11, 1907.*]

Mr. President and Members of the Association: In 1872, when the city took over from the Springfield Aqueduct Company the plant from which the water was supplied to the city, Springfield was situated in large part on the lower level along the river, on the plain upon which this hotel (the Cooley) is situated, and did not extend at that time to any considerable extent to the higher region. The population in 1870 was about 26 000, and the city had just reached the stage when more water was necessary. It was accordingly necessary, as one of the first acts of the city in its municipal rôle of water seller, to obtain a new water supply.

Several of the experts of the time were called and the various upland streams in the vicinity were studied, as was also the question of supply from the Connecticut River. At that time there was a report presented in favor of the Westfield Little River, the supply which the city is just now taking. This was found, however, to be too expensive for a city of 25 000 people. Cast-iron pipe was pretty high in those days, and there was a good deal of labor involved in getting the water out from the gorge.

As a consequence a scheme was developed by which it was planned to take water from several branches of Broad Brook, lying in the towns of Ludlow and Belchertown,— very largely in Ludlow, — and this was the water taken at that time. It was possible at a very reasonable cost to throw a couple of dams across the two small outlets of a large swamp and flow what is now known as the Ludlow reservoir, with an area of about 445 acres and with a possible capacity at high water of nearly 2 000 000 000 gallons. This, it was thought, would supply water for a considerable time. It had the added advantage that it stood some 160 feet, I believe, above the higher portion of the city, and although it was 12 miles

distant from Main Street, it was possible, with a 24-inch cement-lined pipe, to deliver a sufficient quantity of water under pressure to all parts of the city. Just at that time the city was growing eastward, or toward that supply.

That is, in general, the history of the taking of the Ludlow water. The supply from the first began to develop, in the summer time, unpleasant tastes and odors, and the records of the gate-keeper in those earlier days show that the water every year, from the very first summer, developed a green growth, which made the water very objectionable in appearance as well as for drinking purposes.

After several years, these disagreeable tastes and odors appearing each year for varying lengths of time,— some years for not more than a few weeks, and other years extending over two months or more,—it was found that the city would need more water, and in about 1890 or 1892,— I am not certain of the exact date,— another tributary was added to the Ludlow reservoir by means of a canal seven miles in length. It was hoped that this would not only furnish more water to the growing city, but would also cause circulation through the reservoir, improving the quality of the water and rendering the supply adequate for a longer period. This was done, and in fact from all I can learn from the records and from the testimony of the people who had to use the water before and since, it did make a considerable improvement, and the water was bad for a shorter portion of the year.

However, as time went on, the tastes and odors became more objectionable again, and in time the capacity of the supply was again inadequate, if we should consider the possibility of as dry years as had already been experienced, and the growing size of the city. In order to supply water during the time when the Ludlow reservoir was bad, three smaller ponds lying between the city and the Ludlow reservoir were taken, Chapin, Loon and Five Mile ponds. These ponds are in reality springs in a sandy soil, and they furnish a very clear, nice-appearing water. They are on a lower level than the main supply and consequently have to be pumped. These ponds cover, on an average, an area of about 30 acres each and have no feeding streams tributary to them, and but one of them has any outlet. It is, therefore, apparent that

they represent merely stored ground water, and their capacity is limited to that of the storage capacity of the surrounding sand. It has been found that the city could draw upon them for a little over 6 000 000 gallons per day during a period which will not exceed thirty or forty days, at the expiration of which the ground water of the ponds and the region about them would both be at a very low stage. They were particularly valuable in furnishing an exceptional quality of water at just the desired time, but their capacity was not quite sufficient to make up the total deficiency or to cover in extent of time the period of bad Ludlow water. Accordingly, the Jabish brook water was diverted about the reservoir, as is shown in the accompanying diagram, and was used directly from the small basin. While this was necessary in order to make up the necessary quantity of clear water, it was objectionable in that great care was necessary to prevent pollution, inasmuch as the water was used without having been held in storage even for a short time.

As the city continued to grow it was found that something would have to be done. A great many in the city did not attempt to use the water at all in the summer time; others filtered it, using a small house filter. This, of course, made an added item of expense to each consumer, and in general the quality was unsatisfactory. In addition to this was the fact that the time would soon come when there would not be water enough unless either additional storage should be obtained on the watershed or a new supply should be taken.

The history of the discussion over this problem is a long one, and there was a good deal of feeling on both sides, many feeling that Ludlow water, although not all it should be, could be made satisfactory, or at least usable, and that this should be done. On the other hand, those who looked into the future of the city thought that perhaps with the continued growth even more water would be necesssary, and that, on account of the necessity of large expenditure for the purification of Ludlow water, as well as the additional expense of further development, it would be better to go directly to some other supply.

After a number of attempts at securing legislation for various supplies, in the fall of 1905 all parties agreed upon a method of

procedure, which was adopted, and it has been carried into effect. That was, first, the construction at the Ludlow reservoir of a filter designed to remove the tastes and odors, or at least to help in the removal of the tastes and odors, during that season when it was objectionable, inasmuch as the water during the colder portion of the year was by no means unsatisfactory; and second, at the same time that this filter was ordered at the Ludlow reservoir it was voted to ask legislative permission to take for a new supply the waters of the Westfield Little River. In round numbers the total Ludlow sources have some 20 square miles of watershed, and Little River some 48 or 50. They are situated about equally distant from the city, the Ludlow source to the east and the Little River source to the west.

An added call for a new supply was made because of the insufficient height of the Ludlow reservoir. The hill section of the city has developed very rapidly, many higher points being now occupied than were at the time the Ludlow supply was taken, and as a consequence the need of more pressure was quite apparent. This, of course, could be obtained from a new supply, and probably obtained more cheaply, it was thought, than by raising the Ludlow supply to some greater height or by laying much larger mains.

This compromise plan was carried out successfully, the legislative permission for the taking of Little River was secured in April, 1906, a little over a year ago, and by July, 1906, the filter which was ordered in the November previous was in working order at the Ludlow reservoir.

Just a word as to this filter. The studies on the Ludlow water have covered a considerable period of time. In 1901 the state board of health, together with Mr. Percy M. Blake, operated experimental filters at the reservoir for about thirteen or fourteen months, and it was found that, with the exception of the summer period, the water could be treated very easily, but during the summer period the tastes and odors were never fully removed. Following this, in addition to many other experiments by the board of health, in 1903 Mr. S. M. Gray and Mr. G. W. Fuller were appointed by the Special Commission on Water Supply, who were to study this phase of the question, to look into the problem of a new supply. During that summer I was employed by these

engineers to study the Ludlow water, and during the Anabæna season twelve filters were operated. From no filter during that time was entirely satisfactory water secured. It was found that in the sand filters as operated the organic matter would clog the bed and an exceedingly disagreeable odor would be developed unless a rather high rate was maintained.

I will not go into these experiments, but following them the report was made that while the water could be purified, it would be by means of double filtration and with triple aëration, as it was found that it was the aërating of the water and the furnishing

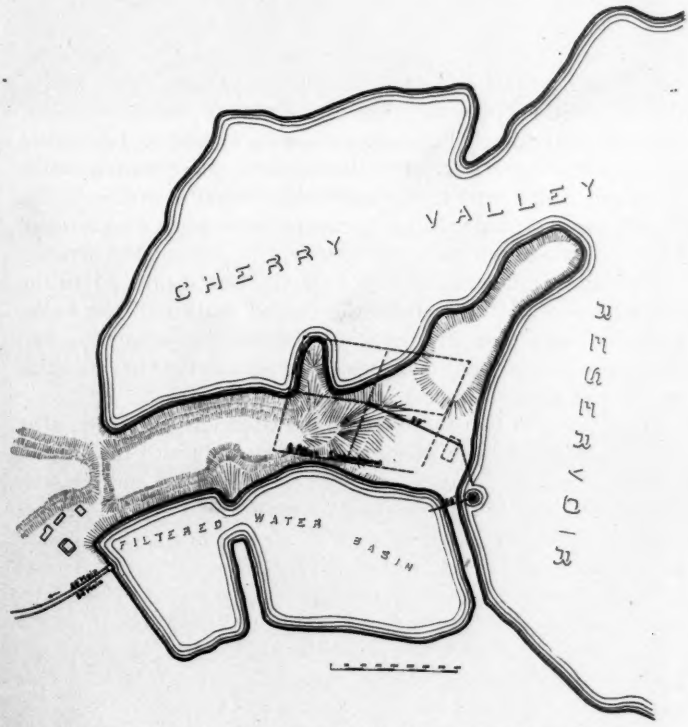


FIG. 1. GENERAL PLAN SHOWING LOCATION OF LUDLOW FILTERS.

of sufficient oxygen to entirely remove the objectionable odors that was necessary to furnish an effluent of desirable quality.

As a consequence, when Mr. Allen Hazen was called upon to furnish a filter that should be both cheap and very efficacious in its action, he was confronted with a problem that I think he was hardly expected to solve.

This filter as designed was to be of sand, put in by analysis only and not by washing, directly from the sandbanks near the site of the filter. The water was to be pumped upon the beds and the usual height of the reservoir used for pressure in the city as heretofore. These filters cover practically four acres in extent and are of a depth of five feet of sand over tiled underdrains laid directly on the subgrade, with no concrete or other bottom. These are all connected into a main central drain, which carries the filtered water out to the clear water reservoir or basin, which, before the construction of the filter, was the controlling basin for the city. The filter was operated through the season of 1906 and furnished very satisfactory water. It is designed to give aëration before the water is delivered to the filter bed, so that even though the regular reservoir water is highly charged with organic matter and has but little dissolved oxygen, it will be thoroughly aërated. Following the filtration, it falls from the lateral drains into the central drain and again from the central drain into the basin, giving in each case an additional aëration following filtration. This was to rid it of any odors which would pass the filter, and also give a well-aërated water for use.

In addition to this the beds are operated intermittently, that is, for sixteen hours or longer if necessary to furnish the supply, but on an average of about sixteen hours each day, and then the beds are allowed to rest and to have air drawn through them so that the sand will become filled with air and in this way supply additional oxygen to the beds. In this the lesson, learned from the earlier experiments, that aëration was one of the essential features of the purification of this water, was made use of.

During the season of 1906 Mr. G. H. Shaw was in charge of the operation, and the results were quite satisfactory. However, at no time during that year did we have the amount of Anabæna (which is the bugbear of the reservoir) that we have had in a good

FIG 1. GENERAL VIEW LUDLOW INTERMITTENT FILTER, SHOWING ARRANGEMENT. AËRATOR IN CENTER. BED IN DISTANCE IN PROCESS OF CLEANING, REMAINING THREE BEDS IN OPERATION.

FIG. 2. LUDLOW INTERMITTENT FILTER. LOOKING ACROSS ONE BED, SHOWING SAND EMBANKMENT WHICH SEPARATES BEDS, ALSO AËRATOR.

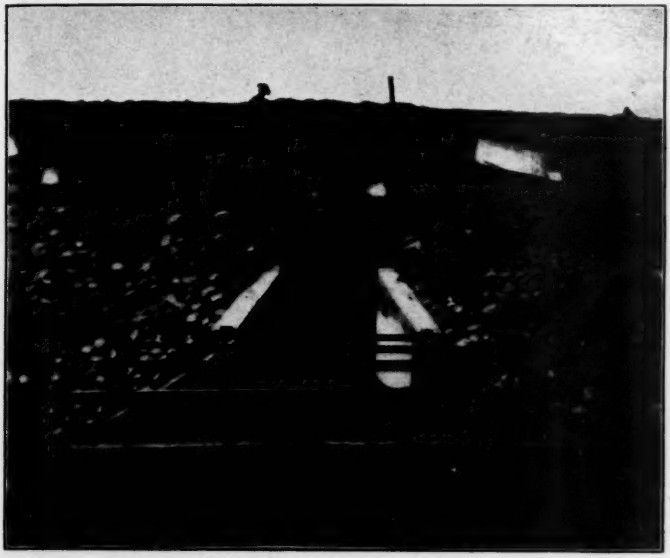


FIG. 1. LUDLOW INTERMITTENT FILTER. CENTRAL CONCRETE DRAIN AND WOODEN FLUME. POINT AT WHICH ALL FILTERED WATER LEAVES FILTERS. THE FLUME CARRIES THE WATER 100 FEET OUT OVER OPEN FILTERED WATER BASIN TO POINT THAT IS DEEP ENOUGH TO ALLOW FREE FALL OF EFFLUENT FOR FINAL AËRATION.

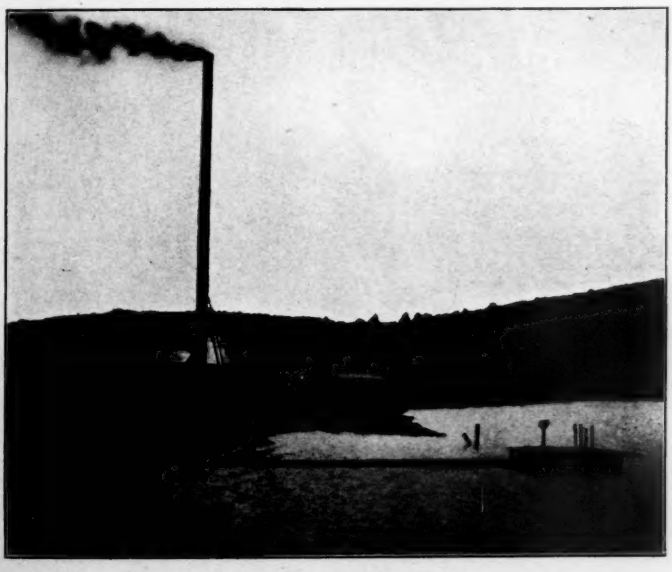


FIG. 2. LUDLOW INTERMITTENT FILTER PUMPING STATION AND LABORATORY. SHOWS 36" INTAKE.

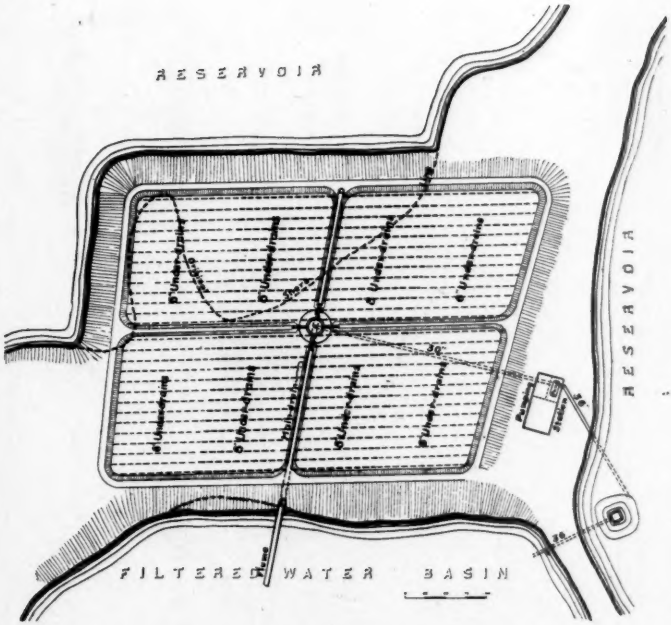


FIG. 2. PLAN OF LUDLOW FILTERS.

many seasons past, so we were afraid that perhaps we had not had representative results and that there would be seasons to come when the water could not be successfully handled. During the present season Mr. C. F. Story has operated the filter and has had some more difficult water to handle. The amount of Anabæna has been very much higher in the reservoir, and the amount of Uroglena at one time was much in excess of any we had before. The duration of the epidemic, however, was not as long as it has been in past years. However, at all times very satisfactory water has been produced. It has not always been entirely free from tastes and odors as it entered the basin, but it has been substantially free, and it has furnished a water which has been quite

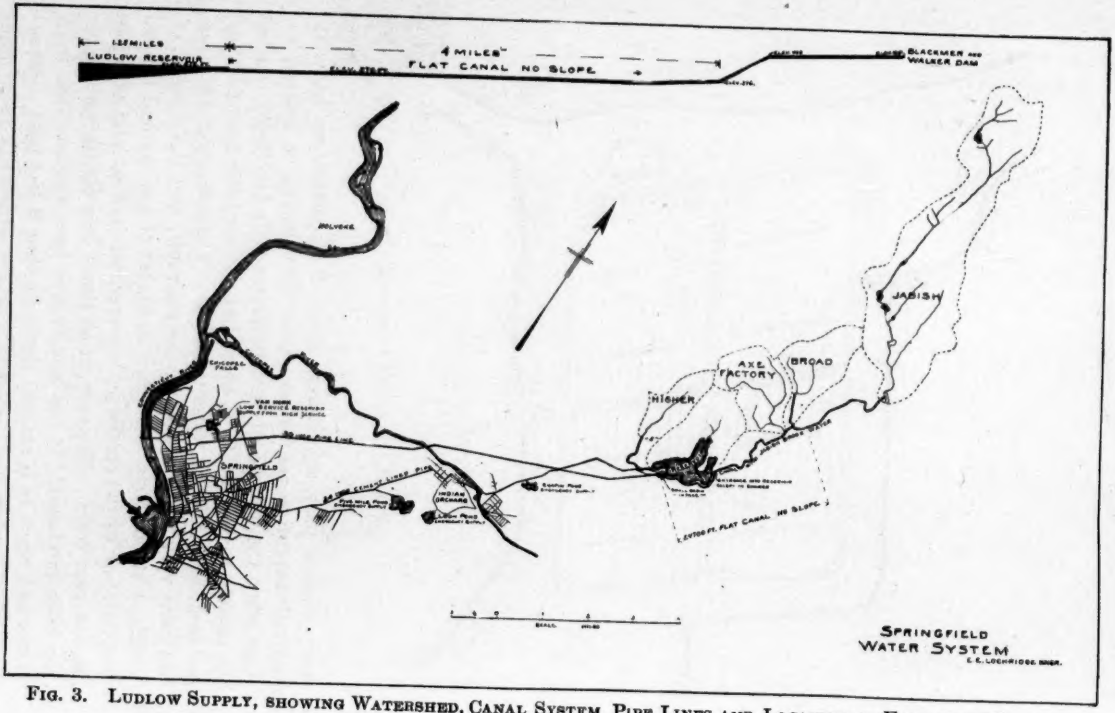


FIG. 3. LUDLOW SUPPLY, SHOWING WATERSHED, CANAL SYSTEM, PIPE LINES AND LOCATION OF EMERGENCY SUPPLIES.

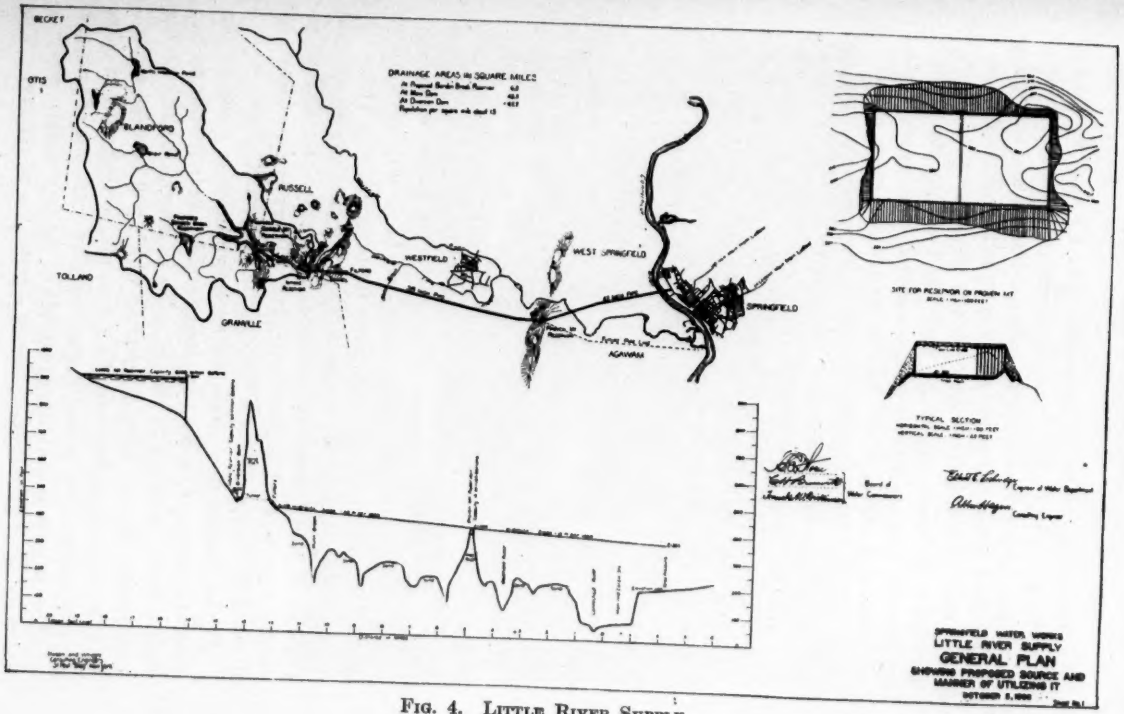


FIG. 4. LITTLE RIVER SUPPLY.

acceptable, I believe, to the consumers, and far more acceptable than any water we have had in any summer for a great many years.

With this filter thus established between seasons, and something done for the Ludlow water, the city was united in asking for a new supply, and with the acceptance by the city council of the Act authorizing the new supply, the work has been started to bring into the city, from an entirely separate source, in an exactly opposite direction, a supply which will be complete in every way.

It is planned to bring this in with a pressure of about 140 pounds on Main Street and about 70 in the hill section, which is 130 feet higher than Main Street.

This new supply has several features which are very desirable in a city system and which are not present in the old supply. It is taken from a very sparsely settled region; I believe with about 13 inhabitants per square mile. The region is mountainous, and the diversion of the water is from a gorge into which no road has ever been made, unless it was a logging road at one or two of the more accessible points, but a large portion of the gorge has never even been wooded on account of its steep nature. The sites for storage on the main stream are excellent. On the Ludlow system the water is all diverted by means of a long flat canal, and the main storage, the Ludlow reservoir, has practically no watershed of its own. While at present the requisite storage will be obtained from reservoirs on tributaries, a site is available which will supply enough water ultimately to supply the city until it shall become three or more times its present size. There are sites for filtration of the entire supply without loss of head or pressure in the city, as would have been necessary had the Ludlow supply been filtered without pumping. There is also within 4¼ miles of the city a site for a distributing reservoir.

At the present time, when an excessive draft is made on the present system, we have a very considerable loss in friction on two main pipes of between 11 and 12 miles in length; while with the new system we will have a reservoir which will be near enough, or at least much nearer than the old supply, so that a fire or other excessive draft may be maintained without great loss of pressure.

There will be several other features of the new supply, which is to be put in at an estimated cost of a little over $2 000 000. This

PLATE III.

LITTLE RIVER SUPPLY — GORGE SHOWING NATURE OF STREAM.

is to be one of the few supplies, in this region at least, which will be taken from a mountainous source and filtered before it is used, the filter to be constructed before any water is taken. Filters have been built for supplies which receive more or less sewage, but as far as can be determined, this supply receives no sewage whatever, and, with the sparsely settled country, very little pollution of any kind.

At the present time, storage will be provided on one of the tributaries to the stream, and in this storage it will be possible to secure something like 2 000 000 000 gallons of water, with an area of only about 190 acres, making a much deeper reservoir for the storage than in the present system. The diversion dam, for which, together with the tunnel, the contract has just been let, is to be of cyclopean masonry and is to rise about 50 feet above the bed of the stream. The tunnel, 4 530 feet in length, will bring the water through the mountains to the filter site, from which a steel pipe will be carried across a very open country with but little ledge, and across land that is very largely sand, to the distributing reservoir on Proven Mountain, where a sufficient quantity can be held in reserve to equalize the fluctuations in the demand for water in the city. An additional feature will be the Connecticut River crossing and the connection with the city's mains.

An additional problem which the city has had to meet is that of its piping in the city. The supply coming from the east was brought in first through the residential section, and the mains were lessened in size as they approached the Connecticut River. Bringing in the supply from the west will necessitate the connecting of these mains in some way that the pressure may not only be properly maintained, but water provided for the city of the future.

There is a large amount of old pipe in the streets, and there is a large part of the city which is not at present gridironed, that is, there are no connections through to the neighboring streets. For example, Main Street is supplied with a 16-inch pipe running the greater length of the street, while Water Street (the next street toward the river and the one adjoining the river) is not supplied with any high-service pipe at all, while the side business streets extending off from Main Street are supplied only with small pipes

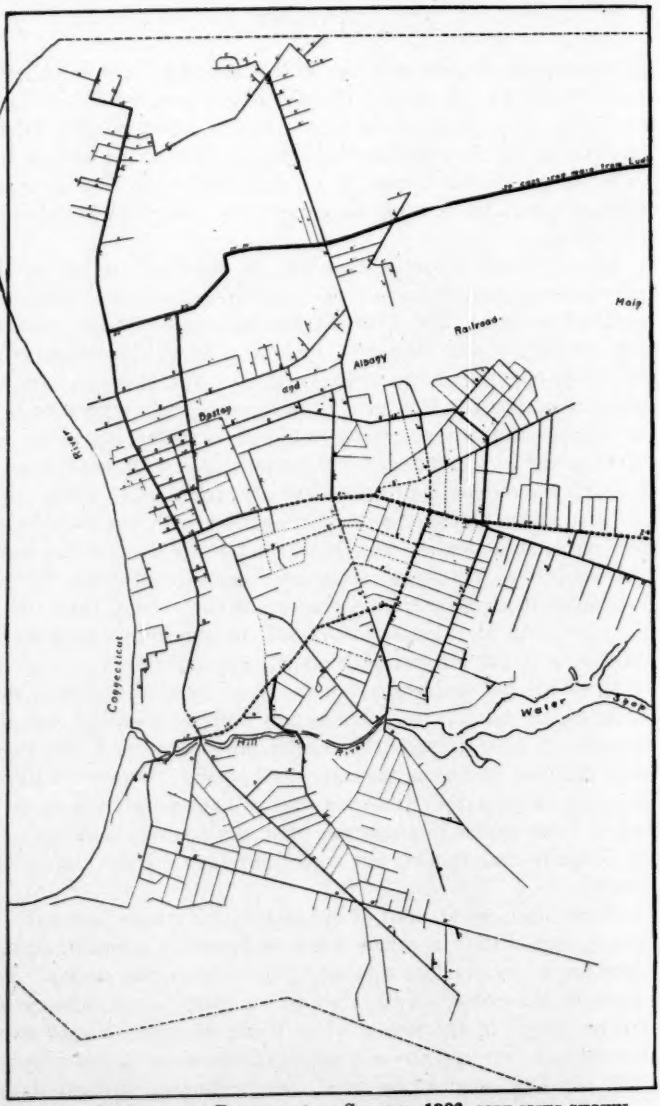


FIG. 5. SPRINGFIELD DISTRIBUTION SYSTEM, 1906, PIPE SIZES SHOWN RELATIVELY. DOTTED LINES INDICATE CEMENT-LINED PIPES.

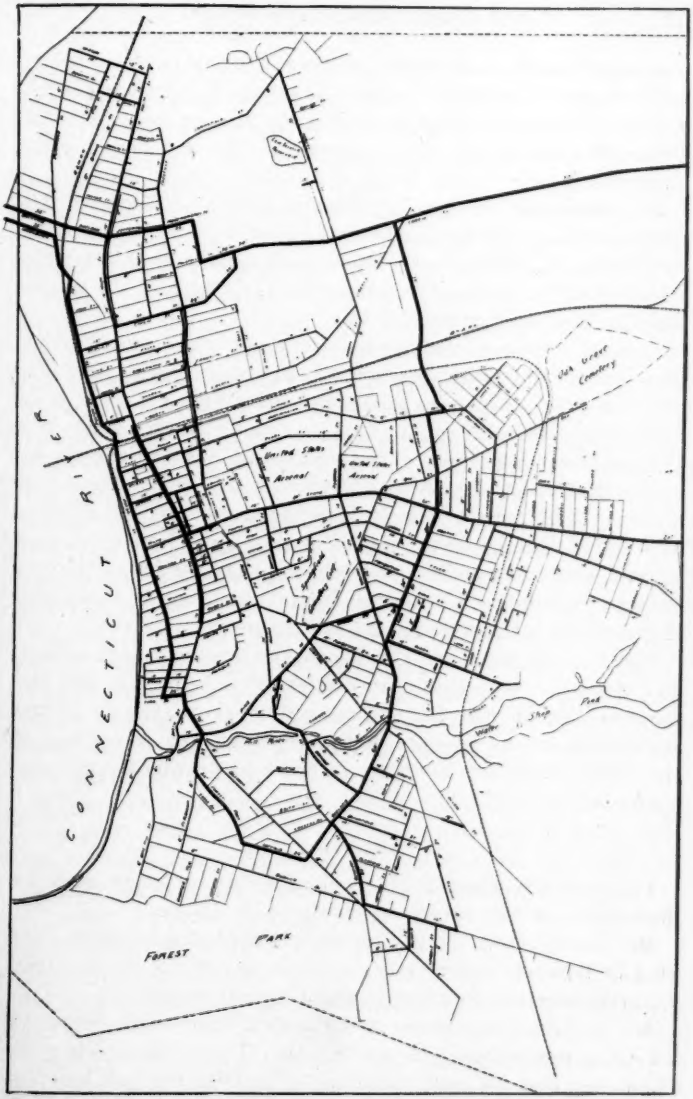


FIG. 6. SPRINGFIELD DISTRIBUTION SYSTEM, SHOWING CIRCUIT OF LARGE PIPE AROUND CITY. THESE CHANGES NOW BEING MADE, ABOUT 20% HAVING BEEN COMPLETED IN 1907.

which lead merely to dead ends at the end or middle of the block. It is necessary, therefore, in order to get the best system for the city, to reconstruct, or to bring in some manner, pipes to these streets, of sufficient size for fire purposes. This has been no small problem.

Mr. Hazen and Mr. John R. Freeman have both discussed this matter with us, and the matter was placed with Mr. Hazen, who secured Mr. R. D. Chase, who spent some months in studying the question of the proper fire service for the city and the proper distribution of the mains.

I will show you on the screen something of the problem which they had and the means which has been obtained of furnishing a good fire service to all parts of the city. (See Figs. 5 and 6.) This has been, or will be, accomplished by a belt main line about and through the main portions of the business and residential sections, a little over seven miles in length, which will be from 36 inches in diameter at the largest point to 24 inches, and at no point smaller. This will furnish the feeder which will draw water from either east or west, as may be needed, and deliver to any portion of the city the water under the full pressure, from which it can be taken into the smaller pipes and gridironed as may be needed.

This work of rebuilding the distribution system is well started, and this year considerably over $100 000 is being put into the improvement on the distribution system alone, largely in the starting of this circuit and in the extension and connection of the mains where it is necessary in order to provide for the new conditions.

DISCUSSION.

PRESIDENT WHITNEY. Mr. Lochridge's paper is now open for discussion. We should like to hear from Mr. Hazen.

MR. ALLEN HAZEN. Mr. President, ladies and gentlemen: I am glad to have an opportunity to add a few words to what Mr. Lochridge has said about the Springfield water works.

Mr. Lochridge has spoken of the Ludlow filter which was put in service at the beginning of last summer. I don't think it is quite fair to say that we built this filter. The filter was half built by nature before our work was started. It must have been some kind

foresight of Providence that put 100 000 yards or so of filter sand and gravel close to the Ludlow reservoir, and in fact partly in it, all ready to be tipped over with a steam shovel and made into a filter of the kind which you will see when you visit it. That was substantially the condition at Ludlow, and it was a novel condition, and we were able to utilize it fully for the benefit of the city.

There is another matter about the construction of this filter. It was built to a considerable extent in winter. The work was decided upon and authorized late in November. The filter was finished and put in service early in July following, before the worst summer condition of the water in the reservoir. And I want to say right here that the credit for building so large a filter in so short a time, and partly during winter months, is due to Mr. Lochridge and to Mr. Stone, the chairman of the Board of Water Commissioners. There was some steering from New York, but the pushing that enabled the filter to be built in so short a time was given by the two gentlemen named.

Mr. Lochridge has spoken of the long-continued experiments upon the treatment of the Ludlow water by Mr. Blake, and by Mr. Gray and Mr. Fuller, and by the state board of health, and he spoke of the fact that these experiments did not lead to a method of treatment that was at once economical and sufficient. It is true that the water was successfully purified in some of these experiments, but only by the use of double filtration under conditions which would have meant a very large expense for the construction and operation of a plant.

Ludlow water is pretty bad. I don't think that I need enlarge upon that. When we were at a legislative hearing some years ago, we told the committee that, as far as we knew, Springfield had the worst water supply of any considerable city in the state.

I speak of this to show that the problem which was considered in the experiments was a difficult one and a novel one. There were conditions that had not been met before, and it is not surprising that the first experiments did not lead to entire success with it.

And I wish to state at this time that while these experiments did not develop a sure and economical method for the complete purification of Ludlow water, they did serve to lay the foundation

for the method afterwards adopted; and I am glad of an opportunity to put this fact upon record to-day.

These experiments, in the first place, served to demonstrate that some methods and processes, which otherwise certainly would have been considered, would not succeed in the treatment of Ludlow water, and they served to give a good idea of the nature of the water and of how it acted under various conditions, and suggested the lines of modification of the treatments that were tested that would be most likely to prove successful.

And in studying the question some help was derived from the knowledge of sewage purification works. The organic matter that is most troublesome in this Ludlow water is chemically more or less like the organic matter in sewage, and it seems to be capable of being removed by the same methods. Sewage contains more organic matter than Ludlow water even at its worst, and a study of the methods of sewage purification which have successfully removed organic matters was of material aid in arriving at the design adopted at Ludlow.

The Ludlow filter as constructed had no direct precedent. It was to some extent an experiment. It was certain that it would make the water a good deal better, but it was not certain just how much better. The filter, therefore, was an experiment; but is differed from the experiments that went before in that it was conducted on a much larger scale and the effluent was put into the service pipes, and the people of Springfield were, therefore, made parties to the experiment and were able to judge of the results that were produced. And these results have greatly exceeded our expectations.

The Ludlow water is purified by this filter to such an extent that if quality were the only consideration, the people of Springfield would, I believe, be satisfied with water of the quality that they have received since the filter was put in operation. But the amount of water that can be drawn from Ludlow is limited. Springfield is growing rapidly and will certainly need much more water than is now used. In a wet year, or an average year, the Ludlow reservoir is able to maintain the supply that is now taken, but in a dry year it would be entirely unable to maintain that supply. Fortunately, in the last few years, since the consumption

has become so great, there has been no very dry year. Further, the pipes from Ludlow to the city are too small; the storage capacity is hardly enough; and if the supply were to be continued in use, new reservoirs, new filters, new pipe lines to the city, and, in fact, substantially a whole new plant would be required, as was conclusively shown by the report of Messrs. Gray and Fuller upon the Ludlow water. And this new plant would cost almost as much as the supply from a new source that is proposed.

Mr. Lochridge has told you about the Little River supply which has been authorized and upon which work is just being started. The design of this supply has presented some questions of the greatest interest. One of these is as to the most desirable pressure or elevation at which to deliver the water in Springfield.

Most of the Little River watershed has a great elevation. The main dam, which it is proposed to build sometime in the future, will have its flow-line some 900 feet above tide. It is physically possible to bring the Little River water into Springfield at any pressure that might be desired. It would certainly be possible physically to bring the water in with a pressure of 300 pounds per square inch, although it would cost a great deal of money to secure such a pressure.

The question to be determined was what pressure would be most desirable, all things considered, and taking into account the added expense involved in securing additional pressure. And there was also the question as to whether the city could best be served in two service districts, with high and low services, or whether it would be better to combine all in one system, with a moderate pressure in the higher parts and a rather high pressure in the lower parts of the city. Mr. Lochridge has already spoken of this problem of arranging the distribution.

The old part of the city along the river bank is but little elevated above it. Most of the larger and higher buildings of the city are in this low, flat area. Back of this area are bluffs of sand, with steep sides. The tops of the bluffs form a level plain of sand, extending back for miles, with here and there a valley cut by a stream or a rise of moderate elevation above the general level. On this sand plain the city has grown rapidly in the last years, and the greatest growth is now upon it.

There was a good deal to be said in favor of the proposition to have two separate services, a high service for the elevated plain, and a low service for the river bottom; but the arrangement of the piping could be more conveniently and cheaply made for a single system, and the single system unquestionably provided best for the concentration of large quantities of water wherever it might be needed in the case of an extended fire or conflagration.

These questions were taken up with Mr. John R. Freeman, and after studies were made of different projects and of the possibilities of reservoir sites, he advised us to adopt one system for the whole city.

The single system is cheaper, simpler, and, as he thinks and as we think, it is better. This single system which is adopted means that a pressure of 130 to 140 pounds will be carried on the river bottom, and that a pressure of 70 to 80 pounds will be carried on the sand plain immediately on top of the bluff and the center of the city in the immediate neighborhood of the United States Armory, and that somewhat smaller pressures will be carried in the highest and most remote points of the city.

The site selected for the distributing reservoir is on Proven Mountain and is the only site within a corresponding distance of the city at sufficient elevation to maintain this pressure. It is very fortunate that it was possible to locate the new works so as to take advantage of this distributing reservoir site, and it was also very fortunate that a saddle was found at the right elevation in the ridge, which usually is of trap rock and too narrow and steep to afford a satisfactory site. The site selected is sufficient not only for the construction of the reservoir which is now proposed, but will also serve for an addition of another part of equal size when the growth of the city makes it desirable.

The proposed Little River works are designed all the way through with reference to extension. A 15 000 000-gallon plant is now being built, but everything is designed for an ultimate extension of double, or more than double, that capacity.

The Little River water is to be filtered, although it comes from a hilly and almost mountainous watershed that has but little population upon it. Filtering the water adds something like $300 000 to the cost of the project. It insures the delivery of a

water of greater attractiveness from a physical standpoint, and it largely eliminates possible danger of disease which might come from accidental contamination of the sources.

The filtered water is to be stored in a covered reservoir, that is to say, in the distribution reservoir on Proven Mountain. Covering this reservoir is also something of a novelty for a supply of this character. The cover is provided to keep out the light and to prevent the growth of organisms in the reservoir, which growths tend to reduce the quality of the water.

At Ludlow, as you will see on Friday when you visit the present filter, the effluent is stored in an open reservoir, called the Little Basin, which is a part of the Ludlow reservoir cut off by an embankment; and in that little basin you will see that there are growths of organisms, and the water flowing from it to the city is not of quite as good quality as the water that comes from the filters. This condition of storage of effluent in an open reservoir, with a consequent deterioration in quality, was tolerated in the Ludlow design because the whole purification plant is for temporary service, and it was, therefore, wise to take some chances on deterioration rather than spend the large additional sum required to prevent it, as we should wish to do if it was for permanent service. But in the Little River supply we propose to keep all filtered water in the dark and bring it into Springfield in just as good condition as it leaves the filters, and so attractive and wholesome that there will not be any excuse for the spring water business to exist.

Springfield started with the worst water supply of any considerable city in the state. It is the ambition of the water board and of Mr. Lochridge, and of the speaker, to carry out the works now authorized in such a way as to provide Springfield with the best water supply of any considerable city in the state.

MR. LOCHRIDGE. Mr. President, I don't know as there is any way of describing the water when it is impregnated with Anabæna unless you have seen it, and you have got to multiply it after it is described. I will let each of you do that.

The reservoir, covering something over 400 acres, is, during the summer, filled with small, hairlike substances or filaments, which are in reality the filaments of this Anabæna. Looked at under a

microscope, they are made up of small beads, and they are each of them about two thousandths of an inch in diameter, although the filament may be half an inch long.

The water is entirely filled with this to such an extent that if you should put your hand below the surface, holding it straight below the surface, it could not be seen at all at a depth of three inches. It is frequently that way, and I haven't a doubt that some of the people who are here, that I know have lived here a good many years, could tell you they had seen it in the pipes almost as bad, but we always tell them that the water they get in the pipes is diluted, that some of it runs around the reservoir from the brook. That is one way of describing it.

Following this period, and it isn't very bad at this time,— you can drink it, it isn't very bad yet,— they begin to die and then you begin to get your tastes and odors. The oil sacs are liberated, and it was in this that one of the big problems of the filtration came.

The Anabæna in its fresh stage is handled by the filter quite easily, but when it begins to die, and you have this organic matter in this enormous quantity, in some state of decomposition, you have a form that we choose to refer to as secondary odors, and it is these secondary odors which are, to a certain extent, developed in the pipes in the passage for some 10 or 12 miles in the dark. That is the odor which it is hard to remove by filtration; in fact, the filter won't do it; it has got to be aërated following the filtration.

During 1903, when I was at the reservoir, this stage I have described lasted from the first day of August through till some time in October; that is, over two months — all of August and September. When the cold weather comes on, it coagulates; that brings it up. And the Anabæna has, in addition to the chlorophyl,— the green coloring which we know in all plants,— cyanophyl, which is a blue coloring matter. These colors separate, and the whole mass comes up and covers something like 40 or 50 acres of the reservoir. It usually gathers together in some such mass. I have seen it a number of times. That mass is from three to four inches thick, and you can put your hand in and lift out quite a good-sized cake of it. But you have got to hold it pretty carefully. It will go through rather a fine mesh. It is in

blue and green streaks. After a person visits the reservoir and looks at that, he goes home and doesn't drink the water for a year. I have had several tell me that that is exactly what they did. In reality this mass has all come out of the water before they get it in the pipes. It is not in such a bad state, but the breaking up of this matter makes a taste and odor which are decidedly objectionable, and of the worst form for the treatment by filtration and aëration.

At the time of this formation of the jelly-like mass, which always follows the period of the excessive Anabæna count, a stone the size of your fist can be rolled out upon it and it will stay there. I have seen it stay there three or four days, if you will believe it, although you are all welcome not to, as few do unless they see the reservoir during one of its very bad stages.

MR. WESTON. I should like to ask Mr. Lochridge what rate of filtration is usually employed at the Ludlow filter.

MR. LOCHRIDGE. There are four beds of substantially an acre in extent each. We get all the water we want for each day out of that. The use of the city is between ten and twelve million gallons a day. The fact that there is no concrete bottom to the filter means that there is a considerable loss. Perhaps 40 per cent. of that loss makes its way into the basin and isn't a loss, but it doesn't go out through the underdrains. The other 60 per cent., or perhaps more, goes back into the reservoir and is not lost to the system, but is lost to the filtered water basin. And Mr. Story, who has operated the filter this year, and who is present, told me this morning that one fourth of the total amount pumped went through below the underdrains. Three beds are always operated, or practically always. I will try to have it arranged to have one bed off, so that you may see how it is cleaned on Friday when you go out to Ludlow. I don't know whether there will be mud enough on those beds or not, but you will see something about what we have done.

PRESIDENT WHITNEY. I should like to ask Mr. Hazen if this idea of filtering the new supply was the ultimate result of thinking it over, or was it intended at the start?

MR. HAZEN. I don't know as I quite get your question, Mr. President.

PRESIDENT WHITNEY. What I wanted to say was, did you at the start intend to filter this new supply, or was it something which came into the final making of the plans?

MR. HAZEN. Oh, we intended to filter it at the start.

PRESIDENT WHITNEY. Was it considered a necessity?

MR. HAZEN. No, sir; it was regarded as desirable.

MR. MURRAY FORBES. How did you arrive at the conclusion to filter instead of sanitating or purchasing some of the watershed?

MR. HAZEN. We thought we could do a lot more for the money.

PRESIDENT WHITNEY. I wonder if any of the other members present have had experience with this same organism, the Anabæna, — experiences similar to those described by Mr. Lochridge.

MR. HAZEN. I think Mr. Weston has had experience in treating such organisms.

MR. ROBERT SPURR WESTON.* Mr. President, there is not very much to be said beyond a very brief account of some experiments made for the Athol Water Department last summer. The water supply of Athol comes from two impounding reservoirs, one of which, the Phillipston reservoir, is nearly as bad as Ludlow, and is subject to growths of Anabæna, Aphanizomenon, and other organisms. The water commission authorized experiments last summer, and accordingly a small trickling filter of coarse, crushed stone and a small intermittent sand filter were built and operated with the coöperation of the Massachusetts State Board of Health. Analyses were made under the direction of the speaker. These devices were in operation from the first of September to the end of the algæ season, 1906. These devices were practically the trickling filter and the intermittent filter such as are used for sewage disposal, and were operated in a similar manner.

The water in the Phillipston reservoir is deficient in oxygen and abounds in organic matter, and it was thought that the logical remedy for the bad condition of the water would be the removal of the organisms by some method of filtration and the removal, produced by aëration or some other means, of the odor. It was also believed that on account of the deficiency of oxygen continuous filtration would not suffice. The trickling filter was operated at a rate of 2 000 000 gallons per acre per day, water

* Sanitary Expert, Boston, Mass.

being applied continuously. The intermittent sand filter was dosed three or four times a day, and the rate of filtration varied between 200 000 and 1 000 000 gallons per acre per day. The intermittent filter was operated without aëration. It was desired to obtain data for organism removal and aëration independently of one another.

After the first week the effluent from the intermittent filter was nearly colorless and free from turbidity. It had a musty odor, however, but it must be remembered that this filter was purposely operated without aëration.

The effluent from the trickling filter as it came was almost completely free from odor, but it was not free from organisms. Consequently, after a short time, the aërated water again possessed an objectionable odor. Briefly stated, the experiments proved that a thorough aëration would remove the odor from the water and that intermittent filtration would remove most of the color and all the turbidity. The results of operation are as follows:

REMOVAL OF ORGANISMS.

Source.	Average Number of Organisms per c. c.	Percentage Removed.
Phillipston Reservoir	5 637	0
Filter No. 1	2	99.96
Filter No. 2	3 996	30

The almost complete removal of the organisms by Filter No. 1 is noteworthy.

Removal of Odor. The trickling filter No. 2 removed 45 per cent. of the odor, as shown after the samples had been received in the laboratory. Filter No. 1 removed only 10 per cent.

REMOVAL OF COLOR.

Source.	Average Color.	Percentage Removed.
Phillipston Reservoir	0.60	0
Filter No. 1	0.06	90
Filter No. 2	0.54	10

REMOVAL OF ORGANIC MATTER AS SHOWN BY NITROGEN AS FREE AMMONIA. PARTS PER 100 000.

Source.	Average Free Ammonia.	Percentage Removed.
Phillipston Reservoir	0.0100	0
Filter No. 1	0.0021	79
Filter No. 2	0.0131	—31 (apparent increase)

REMOVAL OF ORGANIC MATTER AS SHOWN BY THE TOTAL NITROGEN AS ALBUMINOID AMMONIA. PARTS PER 100 000.

Source.	Average Albuminoid Ammonia.	Percentage Removed.
Phillipston Reservoir	0.0673	0
Filter No. 1	0.0136	80
Filter No. 2	0.0587	13

The logical conclusion from these experiments was that the organisms, and to a great extent their food material, could be removed by intermittent filtration, but that filtration without aëration did not suffice. The experiments also showed that the rate at which the intermittent filter operated, less than 1 000 000 gallons per acre per day, could be increased considerably and still furnish an agreeable effluent.

MR. ROBERT J. THOMAS.* Mr. President, Mr. Lochridge says that one filtration or two filtrations and aëration will not remove the Anabæna, or the trouble from the Anabæna. I would like to ask his opinion of spreading that out on such sand or gravel on a natural slope, perhaps 30 or 40 feet above, and falling into it, three, four, or five hundred feet away from the filtration gallery or collecting gallery; let it filter through this natural sand or gravel into this gallery. Would that remove it, do you think?

MR. LOCHRIDGE. I wouldn't be able to say. We get an immense amount of material, of muck or mud or whatever it is, on top of the sand. If you had sand of just the right kind and made a gravel filter, I should think it would. But we find that our sand very soon becomes used up, covered up, and there is no question but what its life would be short were it not possible to take off the Anabæna which is taken out. And, in fact, every four to ten days during the season, according to the amount of Anabæna and other conditions of the water, it is necessary to take off a layer of the sand, which is practically watertight.

MR. THOMAS. Mr. President, in removing the Anabæna, if I understand, he didn't get satisfactory results with the two filtrations and the aëration.

MR. LOCHRIDGE. That was true in the 1903 experiments which were made; yes, sir.

*Superintendent of Water Works, Lowell, Mass.

MR. THOMAS. Not all of it was removed; some remained in the water?

MR. LOCHRIDGE. Only at the time of the worst water.

MR. WESTON. Mr. President, if I might take the liberty of replying to Mr. Thomas's question, I would say that the essential thing in a filter for the removal of the excessive odor due to organisms is to periodically drain the sand layer and give it fresh air. There is not enough dissolved oxygen in water of the class treated to burn up the large amounts of organic matter which are being stored in the filter day after day. Consequently, the water must receive a treatment more like that given sewage where one doses the filter and then gives it a day's rest in order that the bacteria which effect the destruction of the organic matter may be revivified by the aëration of the bed; it is well known to all that the bacteria which effect the destruction of organic matter, whether in sewage or water, not only live upon the organic matter, but require oxygen as well.

I would like, Mr. President, to ask if the copper sulphate treatment has been considered in Springfield. I would like to ask Mr. Hazen if he has considered it in other cases similar to those outside of Massachusetts.

MR. HAZEN. I suggested the use of copper sulphate, or at least endorsed its use for the Ludlow water, but the state board of health was against us on that point, and as we had to have their coöperation and support in other matters, that matter was not pressed. In other cases I have approved of the use of copper sulphate, where Anabæna has been troublesome, and from it considerable relief has been experienced; but in no case has good clean water been secured by this treatment of the water, corresponding to that which can be obtained by proper filtration and aëration.

MR. M. F. COLLINS.* Mr. President, I should like to ask Mr. Lochridge what effect the size of the sand has on the contents of the filter.

MR. LOCHRIDGE. The sand was analyzed and put in by analysis. That is, one or two men spent their whole time watching the sand bed as it went in. We tried to get sand of 0.35 of a milli-

*Superintendent of Water Works, Lawrence, Mass.

meter. We did get that size for a considerable part of it. I think, however, that while we could get as high as 0.44 at times, or a little higher, that a statement of size of between 0.30 and 0.35 would be about right for all of it, considering the way it was mixed.

PRESIDENT WHITNEY. I should like to ask Mr. Lochridge how uniform that sand runs.

MR. LOCHRIDGE. No uniformity at all; that is, it went in as it was found. The larger stones were eliminated where we could and put in a bucket. If we picked up about a yard, and got but few in it, we let them stay. We raked them off from the top,— that is practically all, — and made a uniform height.

MR. CODD. I should like to ask Mr. Lochridge if the filters handle the Uroglena as effectually as the Anabæna.

MR. LOCHRIDGE. They certainly do some pretty good work on it. I think we had something like 30 000 per cubic centimeter for a while. I don't know how it would hold out for a long period, but we certainly got very good water. It does not handle it as easily; the filters clog up much quicker. Possibly it would require larger filters, and probably it would require greater aëration, but it did handle the water that we had.

PRESIDENT WHITNEY. We should like to hear from Mr. George A. Johnson on this subject.

MR. GEORGE A. JOHNSON.* Filtration problems which have to do with the removal of tastes and odors from water are never very easy of solution. Here at Springfield, however, the promises are strong that this most disagreeable and vexatious phase of the question is being successfully overcome, and the manner in which this is being brought about reflects great credit upon the engineer of the department and his advisers.

In his travels of last year one of the most striking examples of the difficulties to be encountered by water-works men in tropical countries came to the speaker's attention in going over the situation at Singapore, Straits Settlements. Here the supply is derived from small jungle streams draining about 25 square miles of area, much of which is swampy in nature. The water is highly colored as received at the storage reservoir and frequently possesses a strong fishy odor, and the taste is often highly objec-

*Principal Assistant Engineer with Hering & Fuller, New York City.

tionable. The storage reservoir has a capacity of about 1 000 000-000 gallons, corresponding roughly to a storage of 200 days. This long period of storage apparently does not affect the character of the water to any material extent, and on walking around and closely examining the banks of this reservoir, the speaker was unable to detect any signs of algal growth.

The water is filtered before consumption through slow sand filters which, when operated in the usual manner, were not successful in effecting a diminution in the objectionable tastes and odors. In view of this fact the municipal engineer adopted a scheme of operation whereby the beds were allowed to rest empty for a period of about twelve hours in every one or two weeks, maintaining a rate of filtration when in operation of about 1 000 000 gallons per acre daily. According to statements made by those in charge of the works and citizens of Singapore, this intermittent method of operation has proved successful in this case in the more satisfactory treatment of the Singapore water. At the time of the speaker's visit, however, although this method of operation was then in use, the filtered water possessed a strong odor and was quite objectionable to the taste.

With reference to rainfall statistics, some interesting data were found at Calcutta, where, although the annual rainfall amounts to only about 60 inches, as much as 40 inches has fallen in a single week, and quite recent records show that there have been daily rainfalls amounting to as much as 10 to 15 inches.

Few people realize the stupendous progress which is being made by the Japanese in water filtration matters. Although the first public water supply was inaugurated at Tokyo in the year 1600, it was not until 1885 that the first modern system of water-works, including slow sand filters, was put under construction at Yokohama.

At the present time there are 13 cities in Japan, with an aggregate population of 4 000 000, which are supplied with filtered water. In considering the comparative populations of Japan and America, it is seen that Japan practically stands on a par with America so far as her progress in this line of municipal sanitary work is concerned.

The piping systems are quite complete and about one third of

all the service lines are metered. There is a fire hydrant to about every 50 houses. The total cost of all Japanese water works to date is about $11 500 000, or $115 000 per million gallons, or $2.80 per capita.

Very little water is wasted in Japan, as shown by the fact that the average water consumption amounts to no more than 25 gallons per capita per day.

PRESIDENT WHITNEY. I wonder if Mr. Codd would give us his experience with filters.

MR. WM. F. CODD.* Well, I don't know that I can say much about it. We have the Anabæna occasionally, but we haven't done anything with it except avoid it by getting ground water. We haven't been able to filter it successfully. At times it shows very thick in the pond; looks as though one had put valvoline oil into the water. It has about that dark-green appearance. I don't think I can tell you anything about filtering it.

PRESIDENT WHITNEY. I imagine that very few departments are so situated that they can avoid trouble as Mr. Codd does, by using the ground water. We would like to hear the views of Mr. Story, the operator of the filter in Springfield — your views in a general way, Mr. Story, in regard to the operation of the plant.

MR. C. F. STORY.† Mr. President, I don't know that I can add anything to what Mr. Lochridge has said, but I would be very glad to answer any questions along the line of operation and methods. I think perhaps I can tell the members more when they make the trip on Friday.

MR. HAZEN. Tell them about the dissolved oxygen in the effluent.

MR. STORY. I make the practice of taking my samples of dissolved oxygen directly from the small underdrains, so as to get a sample of the water after it has passed through the bed and before it has had any aëration. On a bed that is clean and running at a good rate the dissolved oxygen is always high, and as the bed grows dirtier it drops. In the worst periods of the reservoir water the dissolved oxygen dropped to a point as low as 35 per cent. saturation. At such times the filter gave an effluent which was

* Superintendent of Water Works, Nantucket, Mass.
† Assistant Engineer, Springfield Water Works.

as high as 80 per cent. saturation. I always watch the underdrains closely, and it is my endeavor to shut off a bed, if possible, when the dissolved oxygen in the effluent has dropped to a point less than 70 per cent. saturation. When we find the dissolved oxygen is being reduced in the filtered water, we remove the water from the filter, scrape the bed, and clean it out. In that way the water is always good.

MR. COLLINS. I should like to ask Mr. Story a question. I understand that the operation of this is about sixteen hours a day. I want to know what his rate of filtration is to aërate the sand.

MR. STORY. I wouldn't want to say off-hand, but figuring on the sixteen hours a day, it would be considerably over 3 000 000.

PROF. LEONARD P. KINNICUTT.* What limit do you set to dissolved oxygen before you change the filter, — before taking it off?

MR. STORY. I think I can best express that by saying that we started in June at the reservoir with the dissolved oxygen 90 per cent. saturation, and it ran down during the worst periods to as low as 35 per cent. saturation. The filters when working well always give between 75 and 90 per cent., and I usually took the filter off when it dropped below 70 per cent. saturation.

*Worcester Polytechnic Institute, Worcester, Mass.

PROCEEDINGS.

JUNE 26, 1907.

The annual "field day" of the Association was devoted to an excursion to Gloucester, Mass., by steamer *Cape Ann;* a shore dinner, followed by a trolley ride around Cape Ann; and a return to Boston by train.

No business meeting of the Association was held.

TWENTY-SIXTH ANNUAL CONVENTION, SPRINGFIELD, MASS., SEPTEMBER 11, 12, AND 13, 1907.

The twenty-sixth annual convention of the New England Water Works Association was held at Springfield, Mass., on Wednesday, Thursday, and Friday, September 11, 12, and 13, 1907, at the Cooley Hotel.

The following members and guests were in attendance:

HONORARY MEMBERS.

F. W. Shepperd. — 1.

MEMBERS.

S. A. Agnew, Kenneth Allen, J. M. Anderson, C. H. Baldwin, L. M. Bancroft, F. A. Barbour, H. K. Barrows, G. W. Batchelder, W. U. C. Baton, J. E. Beals, J. F. Bigelow, F. E. Bisbee, G. H. Bishop, J. W. Blackmer, E. M. Blake, C. A. Bogardus, James Burnie, C. H. Campbell, L. G. Carleton, T. J. Carmody, J. C. Chase, J. H. Child, H. W. Clark, W. F. Codd, M. F. Collins, W. R. Conard, J. H. Cook, P. C. Denehy, John Doyle, M. J. Doyle, E. D. Eldredge, E. A. Ellsworth, L. N. Farnum, J. A. Fitch, A. A. Fobes, A. P. Folwell, A. B. Farnham, Murray Forbes, E. H. Foster, A. N. French, F. L. Fuller, S. DeM. Gage, F. J. Gifford, D. H. Gilderson, A. S. Glover, X. H. Goodnough, E. L. Grimes, P. T. W. Hale, R. A. Hale, F. E. Hall, J. C. Hammond, Jr., J. D. Hardy, A. R. Hathaway, W. C. Hawley, N. W. Hayden, Allen Hazen, A. B. Hill, G. A. Johnson, W. E. Johnson, Willard Kent, A. C. King, G. A. King, H. M. King, L. P. Kinnicutt, J. J. Kirkpatrick, E. E. Lochridge, F. H. Luce, S. H. McKenzie, T. H. McKenzie, Hugh McLean, H. B. Machen, C. T. Main, A. E. Martin, D. H. Maury, John Mayo, A. S. Merrill, F. E. Merrill, Leonard Metcalf, H. A. Miller, F. F. Moore, T. W. Norcross, O. A. Parks, Washington Paulison, E. M. Peck, E. L. Peene, E. B. Phelps, A. E. Pickup, A. A. Reimer, W. H.

Richards, H. W. Sanderson, Charles Saville, E. M. Shedd, C. W. Sherman, M. A. Sinclair, H. O. Smith, P. S. Smith, H. T. Sparks, J. F. Sprenkel, G. A. Stacy, W. H. Sutherland, C. F. Story, W. F. Sullivan, R. J. Thomas, W. H. Thomas, J. L. Tighe, J. A. Tilden, D. N. Tower, C. A. Townsend, W. H. Vaughn, J. H. Walsh, C. S. Warde, R. S. Weston, J. C. Whitney, C.-E. A. Winslow, G. E. Winslow, I. S. Wood, Walter Wood, C. L. Wooding, L. C. Wright. — 119.

ASSOCIATES.

Anderson Coupling Company, by Charles E. Pratt; Roy S. Barker; Harold L. Bond Company, by F. M. Bates; Builders Iron Foundry, by A. C. Coulters; Central Foundry Company, by C. F. Blunt; Chapman Valve Manufacturing Company, by Edward F. Hughes, R. W. Wight, W. V. Threlfall, and Edward L. Ross; The Fairbanks Company, by F. A. Leavitt and C. A. Sleeper; Hart Packing Company, by Horace Hart; Hays Manufacturing Company, by T. F. Nagle; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, W. A. Hersey, and William C. Sherwood; International Steam Pump Company, by Samuel Harrison and J. W. Sims; Monarch Valve Manufacturing Company, by W. D. Hosley; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by A. C. Pilcher and G. A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by C. A. Vaughan, F. A. Smith, and H. H. Kinsey; Norwood Engineering Company, by H. W. Hosford and W. G. Ryan; Pitometer Company, by E. M. Blake; Pittsburg Meter Company, by T. C. Clifford and V. E. Arnold; Platt Iron Works Company, by T. H. Hayes; Rensselaer Manufacturing Company, by Fred S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by William Ross; A. P. Smith Manufacturing Company, by F. N. Whitcomb and Anthony P. Smith; Thomson Meter Company, by E. M. Shedd, S. D. Higley, and W. S. Cetti; Union Meter Company, by L. P. Anderson, F. E. Hall, and C. F. Merrill; United Lead Company, by Frederick H. Craig; United States Cast Iron Pipe & Foundry Company, by Thomas H. McGechin and F. W. Nevins; Water Works Equipment Company, by W. H. Van Winkle and W. H. Van Winkle, Jr.; R. D. Wood & Co., by Charles R. Wood and Walter Wood.— 53.

GUESTS.

J. F. Beladeau, H. H. Hawkesworth, Pittsfield, Mass.; F. P. Martin, L. F. Ivers, West Springfield, Mass.; A. A. Adams, F. W. Dickinson, Edwin G. Rude, F. A. Holden, J. J. Fitzgerald, Mr. and Mrs. E. S. Green, Charles Davis, J. K. Barker, Mrs. H. P. Small, H. C. Emerson, George F. Merrill, H. T. Murphy, M. L. Miller, and E. T. Kavanaugh, Springfield, Mass.; L. B. Cummings, F. S. Dewey, Jr., and Chas. N. Oakes, Westfield, Mass.; W. A. Brown, Greenfield, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. Irving S. Wood, Providence, R. I.; P. J. Lucey, F. J. Millane, A. F. Sickman, Robert E. Newcomb, Patrick Gear, James F. Cleary, Miss Alice S. Corner, and Miss K. G. Sullivan, Mrs. E. A. Ellsworth, Holyoke, Mass.; Mrs. H. O. Smith, Leicester,

Mass.; T. A. Collins, Lawrence, Mass.; Mrs. D. H. Gilderson, Haverhill, Mass.; Mrs. Wm. H. Thomas, Hingham, Mass.; Mrs. D. N. Tower, Cohasset, Mass.; Mrs. L. M. Bancroft, Reading, Mass.; Mrs. W. H. Vaughn, Wellesley, Mass.; Mrs. George A. King, Miss King, Taunton, Mass.; Mrs. Murray Forbes, Greensburg, Pa.; Mr. H. P. Keegan, Cleveland, Ohio; Mr. R. Winthrop Pratt, Columbus, Ohio; Roscius C. Newell, Three Rivers, Mass.; James G. Hill, Lowell, Mass.; F. N. Carpenter, Northfield, Vt.; Bertram Brewer, Waltham, Mass.; F. S. Robinson, Waterford, N. Y.; George R. Taylor, Scranton, Pa.; W. H. Jackson, Providence, R. I.; Mrs. John Mayo, Bridgewater, Mass.; H. R. Cooper, Thompsonville, Conn.; Mrs. F. H. Luce, George C. Dickel, Woodhaven, N. Y.; C. A. Goodhue, Thompsonville, Conn.; A. E. Blackmer, Plymouth, Mass.; Joseph M. Brown, East Orange, N. J.; Mrs. W. H. Van Winkle, Thaddeus Newman, G. E. Sly, Frank C. Wright, A. E. Kornfeld, New York City; W. W. Bryan, Paterson, N. J.; Mrs. Ena B. Small, Portland, Me.; Mrs. Edward L. Peene, Yonkers, N. Y.; H. B. Morton, Bristol, Conn.; Edwin Leavitt, Somerville, Mass.; Mrs. E. M. Shedd, West Somerville, Mass.; John J. Barry, Chicopee, Mass.; Mrs. Frank L. Fuller, Harry S. Brown, F. C. Putney, P. H. Gallaher, J. R. Fletcher, T. P. Taylor, E. A. Stevens, Mrs. H. H. Kinsey, Miss Joan M. Ham. — 81.

[Names counted twice — 7.]

The convention was called to order at 12 M., on Wednesday, September 11, in the convention room at the Cooley Hotel, with President John C. Whitney in the chair.

PRESIDENT WHITNEY. I have to announce the opening of the Twenty-Sixth Annual Convention of the New England Water Works Association. We meet this year in a city which has faced and is facing difficult municipal problems in a broad-minded, businesslike way, and I take great pleasure in introducing the Hon. William E. Sanderson, Mayor of the city of Springfield.

MAYOR SANDERSON. *Mr. President, Ladies, and Members of the New England Water Works Association:* It is not my purpose to occupy your time to any extent with remarks of mine, knowing full well that you are here to consider problems which apply to your particular line of business. It is very true that Springfield is confronting problems of great magnitude, and particularly in your line lies one of them. The details of that problem will be presented to you very ably by the engineers of our Water Department.

I cannot help but appreciate — and the people appreciate — these gatherings, where there is an exchange of ideas on the problems confronted in the different localities from which you have the honor to come. It is the exchanging of those ideas which

makes it possible for us to attain the highest degree of efficiency and perfection in these problems which affect the people of our respective communities.

Gentlemen, it affords me great pleasure, on behalf of the city of Springfield, to extend to each and every one of you a most cordial greeting and hearty welcome. We trust that your stay in our city may be most pleasant and profitable to you, and that you may carry away with you pleasant memories of the city of Springfield.

Gentlemen, I thank you.

PRESIDENT WHITNEY. The Secretary has some applications for membership which have been passed upon by the Executive Committee, and which he will read. Mr. Secretary, will you read the applications that you have?

SECRETARY KENT. I have applications for membership from: Henry B. Lake, chemical engineer, Canadian Pacific Railway, Winnipeg, Manitoba; Edward Sutherland Stokes, medical officer and biologist to Metropolitan Board of Water Supply and Sewerage, Sydney, N. S. W., Australia; Arthur C. King, assistant engineer, Increased Water Supply, Springfield, Mass.; Cassius E. Gillette, recently chief engineer, Bureau of Filtration, Philadelphia, Pa.; William McCarthy, superintendent, Bluefield Water Works and Improvement Company, Bluefield, W. Va.; Harrie L. Davenport, water commissioner, South Framingham, Mass.; Carroll F. Story, assistant engineer, Springfield Water Department, Ludlow, Mass.; Henry Richards, trustee, Gardiner Water District, Gardiner, Me.; Frank L. Clapp, superintendent of Water Works, Stoughton, Mass.; and for Associate Membership, from United Lead Company, New York, N. Y.

These applications are all properly endorsed, and have been recommended by your Executive Committee.

PRESIDENT WHITNEY. You have heard the applications. What is your pleasure?

MR. L. M. BANCROFT. Mr. President, I move that the Secretary be authorized to cast one ballot for the election of the applicants named.

Motion seconded and carried. The Secretary thereupon cast a ballot, and the President declared the applicants duly elected.

MR. R. J. THOMAS. Mr. President, I move that the thanks of the Association be extended to his Honor the Mayor for meeting with us to-day.

Motion seconded and carried.

Meeting adjourned.

AFTERNOON SESSION, WEDNESDAY, SEPTEMBER 11, 1907.

President John C. Whitney in the chair.

PRESIDENT WHITNEY. The Secretary has some applications for membership which he will read.

SECRETARY KENT. We have applications from: J. H. Child, superintendent of water works, Wallingford, Conn.; Arthur B. Farnham, city engineer, Pittsfield, Mass.; H. O. Lacount, engineer and assistant secretary, Inspection Department, Associated Factory Mutual Insurance Companies, Boston, Mass.; R. R. Newman, civil engineer with William Wheeler, Boston, Mass.; W. G. Dryden, superintendent, Montreal Water and Power Company, Montreal, Canada; William H. Sutherland, assistant engineer, Montreal Water and Power Company, Montreal, Canada; Lawrence C. Brink, New Paltz, New York; P. F. Carmody, water commissioner, Holyoke, Mass.; and for Associate Membership, Monarch Valve and Manufacturing Company, Springfield, Mass.

These are all properly endorsed and recommended by your Executive Committee.

PRESIDENT WHITNEY. You have heard the list of applications. What action will you take?

MR. COLLINS. Mr. President, I move that the Secretary cast one ballot and that they be declared elected.

Motion seconded and carried. The Secretary then cast a ballot, and the President declared the applicants elected.

MR. CHARLES W. SHERMAN. Mr. President, the constitution requires that at some time during the convention a nominating committee be elected or appointed, to name officers for the ensuing year. In accordance with the usual custom, I offer a motion that the President appoint a nominating committee of five.

PRESIDENT WHITNEY. You have heard Mr. Sherman's motion. Is it seconded?

Motion seconded.

PRESIDENT WHITNEY. It is moved and seconded that the President be authorized to appoint a committee of five to bring in a list of officers for the ensuing year. All those in favor say Aye.

VOICES. Aye.

PRESIDENT WHITNEY. Contrary minded, No. It is a vote.

Mr. Elbert E. Lochridge, chief engineer, Springfield Water Works, then presented a description of the Springfield Water Works, illustrated by stereopticon. The paper was discussed by Messrs. Allen Hazen, Robert Spurr Weston, Murray Forbes, C. F. Story, M. F. Collins, R. J. Thomas, Wm. F. Codd, George A. Johnson, and L. P. Kinnicutt.

Meeting adjourned.

EVENING SESSION, WEDNESDAY, SEPTEMBER 11, 1907.

Mr. Allen Hazen gave a talk on his recent visit to Australia, illustrated with lantern slides of water works and other views of interest.

The next paper was "Description of Plant at Peabody, Mass., involving Construction of Tunnel, New Reservoir, New Pumping Station, and High Duty Worthington Pump," by F. A. Barbour, C. E., Boston, Mass.

Adjourned.

MORNING SESSION, THURSDAY, SEPTEMBER 12, 1907.

President Whitney in the chair, at the opening; later, Vice-President George A. King.

This session was devoted to the general subject of damages resulting from diversion of water. Mr. Charles T. Main, of Boston, read a paper entitled "Computation of the Value of Water Power, and the Damages caused by the Diversion of Water used for Power." Mr. Richard A. Hale, of Lawrence, Mass., followed with a paper on the subject of "Water Rights." A paper entitled "Damages Caused by the Diversion of Water Power," by Mr. Clemens Herschel, of New York, was presented by title, in the absence of the writer.

The discussion was taken up on these three papers jointly, and the following gentlemen took part: Messrs. H. K. Barrows, Leonard Metcalf, W. C. Hawley, Kenneth Allen, Charles T. Main,

George A. King, Richard A. Hale, Charles W. Sherman, J. H. Cook, E. L. Grimes, E. H. Foster, and A. A. Reimer. Mr. E. H. Foster offered the following motion:

"That a committee be appointed by the chair to approach the National Cotton Manufacturers' Association and invite them to appoint a committee, these committees to act as a joint committee to draw up a set of rules to govern the estimation of damage to water privileges by diversion."

Seconded.

Mr. Charles W. Sherman offered the following as a substitute motion:

"That a committee of five be appointed by the President to collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers' Association, or other organizations of mill owners, leading to the formulation of standard rules and methods of computing or assessing damages for the diversion of water."

The substitute motion was accepted by Mr. Foster, and, a vote being taken, it was adopted. (The President subsequently appointed as members of this committee, Messrs. Charles T. Main, Leonard Metcalf, R. A. Hale, Charles E. Chandler, and William Wheeler.)

The Chairman made the following announcement:

The South Norwalk, Conn., sand filters are being constructed for the purification of the public water supply. These filters present some novel features, and should be of considerable interest to members of this Association. The South Norwalk Water Commissioners would be glad to have as many members of the Association as possible visit their plant on Saturday next, and will furnish transportation by automobiles from the South Norwalk station to the filters, a distance of about nine miles, and provide a lunch. If any members of the Association desire to accept this invitation please give their names to the Secretary or Mr. H. W. Clark.

Adjourned.

AFTERNOON SESSION, THURSDAY, SEPTEMBER 12.

President Whitney presided.

Mr. Bertram Brewer, city engineer of Waltham, Mass., read a paper on "The Waltham Reinforced Concrete Reservoir," illustrated by stereopticon. The paper was discussed by Messrs. T. H. McKenzie, Leonard Metcalf, H. K. Barrows, Kenneth Allen, Dabney H. Maury, W. C. Hawley, Allen Hazen, Walter H. Richards, A. A. Reimer, A. Prescott Folwell, Frank L. Fuller, and Mr. Brewer.

Mr. William R. Conard then read a paper entitled, "Cast-Iron Pipe Specifications." It was discussed by Messrs. T. H. McKenzie, W. H. Richards, Walter Wood, A. A. Reimer, Frank L. Fuller, and the author.

Adjourned.

EVENING SESSION, THURSDAY, SEPTEMBER 12.

Mr. Hiram A. Miller gave an illustrated talk on "The Charles River Basin."

The Secretary read applications for membership from the following persons:

J. D. Walker, Belfast, Me..; John J. Kirkpatrick, superintendent, Holyoke Water Works, Holyoke, Mass.; Frank J. Gifford, general foreman, Fall River Water Works, Fall River, Mass.; Chester R. McFarland, superintendent of Water Works, Tampa, Fla.,

all of which had been approved by the Executive Committee.

On motion, the Secretary was authorized to cast the favorable vote of the Association for the applicants, which he did, and they were declared elected.

The President announced his appointments to the committees previously authorized as follows:

Nominating Committee. — Dexter Brackett, Alfred D. Flinn, Robert C. P. Coggshall, Edwin C. Brooks, Frederick W. Gow.

Committee on Water Damages. — Charles T. Main, Leonard Metcalf, R. A. Hale, Charles E. Chandler, and William Wheeler.

PRESIDENT WHITNEY. The Association received an invitation from the Water Commission of South Norwalk to visit their filter plant on Saturday of this week. The invitation was received through Mr. H. W. Clark, but so few members have evinced a

disposition to make the excursion that it will have to be abandoned. Now, in reference to the excursion to-morrow, special trolley cars will leave the front of this hotel at nine o'clock sharp. That means the cars will leave at that time. Members must be on the sidewalk at least five minutes previous to that time.

Mr. E. M. Blake described briefly a new pitometer recording outfit for use in determining the slip of pumps.

Convention adjourned.

Friday, September 13, 1907.

In the forenoon the Association was taken by special electric cars to the works of the Chapman Valve Manufacturing Company, at Indian Orchard, and was entertained by that company. The manufacturing plant was of much interest, and so also was the excellent luncheon that followed. A vote of thanks to the Chapman Valve Manufacturing Company was proposed by Mr. R. J. Thomas, and was carried unanimously.

In the afternoon many of the members visited the Ludlow filters of the Springfield Water Works and others took advantage of the opportunity to visit the Springfield armory.

Report of Committee on Exhibits.

Mr. J. C. Whitney, President,
New England Water Works Association:

Dear Sir, — I hereby submit report of Committee on Exhibits at annual meeting held at Springfield, Mass., September 11–13.

The exhibitors were as follows:

National Meter Company	Meters.
Neptune Meter Company	Meters.
Pittsburg Meter Company	Meters.
A. P. Smith Manufacturing Company,	Photographs and samples of work.
Hersey Manufacturing Company . . .	Meters.
Thomson Meter Company	Meters.
International Steam Pump Company,	Worthington Meters.
Ross Valve Manufacturing Company .	Hydraulic blowing engine and pressure regulating devices.
The Fairbanks Company	Valves and hydrants.
Hays Manufacturing Company . . .	Shut-offs, lead connections and patent lead-pipe joints.

H. Mueller Manufacturing Company	Shut-offs, tapping machine, and general water-works tools.
Monarch Valve Manufacturing Company,	Valves.
United Lead Company	Lead wool.
Union Water Meter Company	Meters and pressure regulators.
Hart Packing Company	Fibrous packing, steam and water.
Anderson Coupling Company	Patent lead pipe joints.
Lead Lined Iron Pipe Company	Lead and tin-lined pipe and fittings.
The Pitometer Company	Pitometer.
Water Works Equipment Company	Photos of tapping machines.
Central Foundry Company	Cast-iron pipe.
Fire and Water Publishing Company.	

Twenty-one associate members availed themselves of the opportunities offered to exhibit.

Space occupied by exhibits, 400 square feet.

Respectfully submitted,

EDWARD F. HUGHES, *Committee.*

EXECUTIVE COMMITTEE.

WEDNESDAY, June 26, 1907, 11.30 A.M.

Meeting of the Executive Committee of the New England Water Works Association, on steamer *Cape Ann, en route*, Boston to Gloucester.

Present: President Whitney, and members, Charles W. Sherman, D. N. Tower, Robert J. Thomas, L. M. Bancroft, George W. Batchelder, George A. King, and Willard Kent.

The following applications were received and recommended for active membership, viz.:

Henry B. Lake, Edmund Sutherland Stokes, Arthur C. King, Cassius E. Gillette, William McCarthy, Harrie L. Davenport, Carroll F. Story, Henry Richards, Frank L. Clapp.

Voted: That the next annual convention of this Association be held at Springfield, Mass., and that the Secretary be a committee to make the necessary arrangements therefor.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

BOSTON, MASS.,
August 20, 1907.

Meeting of the Executive Committee of the New England Water Works Association at Tremont Temple, pursuant to call issued by the Secretary at the request of the President.

Present: President John C. Whitney, and members, Charles W. Sherman, George A. King, A. E. Martin, Lewis M. Bancroft, Robert J. Thomas, and Willard Kent.

The President appointed Mr. Edward F. Hughes of the Chapman Valve Manufacturing Company, 94 Pearl Street, Boston, Mass., a committee in charge of exhibits of Associates for the September convention of 1907.

A communication from the Chapman Valve Manufacturing Company, inviting the Association to inspect their works and

partake of lunch was received and accepted for Friday, September 13.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

SPRINGFIELD, MASS.,
Wednesday, September 11, 1907.

A meeting of the Executive Committee of the New England Water Works Association was held at the Cooley Hotel at 2.30 P.M.

Present: President John C. Whitney, and members, George A. King, A. E. Martin, D. N. Tower, George W. Batchelder, Lewis M. Bancroft, Charles W. Sherman, Robert J. Thomas, and Willard Kent.

The following applications were received and recommended for membership:

J. H. Child, superintendent, Wallingford, Conn.; Arthur B. Farnham, city engineer, Pittsfield, Mass.; H. O. Lacount, engineer and assistant secretary, Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.; R. R. Newman, civil engineer with William Wheeler, Boston, Mass.; John J. Kirkpatrick, superintendent, Holyoke Water Department, Holyoke, Mass.; W. G. Dryden, superintendent, Montreal Water and Power Company, Montreal, Canada; Wm. H. Sutherland, assistant engineer, Montreal Water and Power Company, Montreal, Canada; Lawrence C. Brink, New Paltz, N. Y.; Monarch Valve and Manufacturing Company, Valve Manufacturers, Springfield, Mass.; United Lead Company, Manufacturers, Lead Wool, New York City; Frank J. Gifford, general foreman, Fall River, Mass.; P. J. Carmody, water commissioner, Holyoke, Mass.; J. D. Walker, Belfast, Me.; Chester R. McFarland, superintendent, Water Works, Tampa, Fla.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

Louis P. Collins, ex-mayor of Lawrence, Mass., died at his home in Manchester, N. H., on October 1, 1907, after a lingering illness. He had removed there from Lawrence three years ago. He was treasurer and manager of the Derryfield Lumber Company.

He was born in Sheffield, Ontario, in 1851. He located in Lawrence when a boy, going to work in a sash and blind shop. He gradually advanced until he became treasurer and manager of the Briggs & Allen Company, of that city.

In 1888 he entered politics, and was that year chosen a member of the Lawrence city council. The following year he was elected alderman, and in 1890 was elected mayor.

He joined the New England Water Works Association on December 12, 1894.

BOOK REVIEWS.

CLEAN WATER AND HOW TO GET IT. By Allen Hazen. New York: John Wiley & Sons. 1907. 5½ x 8 inches. vi + 178 pp. With 14 half-tone plates. Price, $1.50.

Mr. Hazen says in his preface, "Its object is to help beginners to understand something of first principles. Members of water boards and water works superintendents have largely passed this stage, and it is therefore not for them."

While this may have been the author's idea in preparing the book, and while most water-works engineers, superintendents, and experienced members of water boards have, no doubt, more or less clear ideas on most of the subjects referred to, very few of them, it is safe to say, have so complete information upon these subjects that they will not learn much that will prove valuable, as well as interesting, from this little book.

The titles of the chapters are: Impounding Reservoir Supplies; Water Supplies from Small Lakes; Supplies from the Great Lakes; Water Supplies from Rivers; Ground Water Supplies; On the Action of Water on Iron Pipes and the Effect thereof on the Quality of the Water; Development of Water Purification in America; On the Nature of the Methods of Purifying Water; On the Application of the Methods of Water Purification, arranged according to the Matters to be removed by the Treatment; Storage of Filtered Water; On the Required Sizes of Filters and Other Parts of Water Works; As to the Pressure under which Water is to be delivered; On the Use and Measurement of Water; Some Financial Aspects; The Laying Out and Construction of Works; On the Financial Management of Publicly Owned Water Works.

To one who knows of Mr. Hazen's broad experience in these lines and the clearness with which he writes, it is hardly necessary to say more; to others, no better advice can be given than to get the book and see for themselves.

ICE FORMATION, WITH SPECIAL REFERENCE TO ANCHOR ICE AND FRAZIL. By Howard T. Barnes, Associate Professor of Physics, McGill University. New York: John Wiley & Sons. 1906. 6 x 9 inches. 257 pp., 40 figs. $3.00.

This book should prove very valuable to those who have to do with the operation of water-works intakes or water-power plants in the northern part of the country, where stoppages from ice are not infrequent, or are avoided only by great care and constant vigilance while the temperature remains below the freezing point.

The St. Lawrence River at Montreal has perhaps given more trouble in this way than any other stream, not only on account of the considerable use for

power, but also because the obstruction caused by ice in the river at the foot of the Lachine Rapids has caused many destructive floods in Montreal. This has caused the problem to be studied there with particular thoroughness, and Professor Barnes has utilized the results of the studies in this book.

Considerable space is devoted to the physical laws relating to the transmission of heat and the formation of ice; to temperature measurements, and to the theories accounting for frazil and anchor ice; and, finally, there is a chapter on methods of overcoming the ice problem in engineering work. To the engineer, this chapter is the most important, and it is to be regretted that it constitutes but 23 pages, or less than 10 per cent. of the book.

THE ANALYSIS AND SOFTENING OF BOILER FEED WATER. By Edmund Wehrenfennig and Fritz Wehrenfennig (Austria). Translated by D. W. Patterson. New York: John Wiley & Sons. 1906. 6 x 9 inches. xiv + 290 pp., 171 figs. $4.00.

This book deals with a problem with which New England water users, fortunately, have little to do, since the waters of this section are generally soft. In the greater part of the country, however, the natural waters, whether derived from streams, lakes, or underground sources, are hard, and their use in steam boilers results in the formation of much scale, except where great precautions are taken. With some waters the use of a suitable boiler compound and a comparatively frequent washing out of the boiler serve to prevent the formation of scale; others, however, can only be rendered fit for boiler use by a chemical softening process.

In this country water-softening has been most frequently resorted to by the railroads and by industrial corporations requiring softer water for boiler feeding than could be obtained except by treatment; but there are a few municipal water supplies which are softened, and it is probably safe to predict that a much larger number of public water supplies will be softened in the future.

The present book treats the problem of water softening from both a chemical and an operating point of view. It is prepared with especial reference to railroad water supplies, but the principles are, of course, equally applicable to other water supplies. It naturally contains no reference to American experience in this work, but the explanation of principles and methods seems very complete. The chapters on "Determination of the Amounts of Reagents" and "Testing the Softening" should prove especially valuable to any one having to do with a water-softening plant.

ELEMENTS OF SANITARY ENGINEERING. By Mansfield Merriman. Third edition. New York: John Wiley & Sons. 1906. 6 x 9 inches. 252 pp., 46 figs. $2.00.

The author says in his preface: "While this volume is primarily intended for the use of students in engineering colleges, its plan and arrangement are

materially different from those of other text-books on water supply and sewerage. The effort has been made to present the subject clearly and concisely in the smallest possible space, giving greater prominence to fundamental principles than to details of construction and operation. It is also hoped that the book may prove useful to municipal officers who have supervision of sanitary works as well as to the public in general, for it presents the guiding principles which should be observed in order to secure a pure water supply or an efficient system of sewerage."

The book is mainly descriptive. It is in no sense a text-book on the design of sanitary works of any kind. The titles of the chapters give a general idea of the subjects treated. They are: Sanitary Science; Water and Its Purification; Water Supply Systems; Sewerage Systems; Disposal of Sewage; Refuse and Garbage; Appendix.

This work should be an excellent text-book for imparting to students a general view of the whole field of sanitary engineering, and any person desiring a broad view of the general subject should find it very interesting and not difficult reading.

THE VENTURI METER AND THE FIRST TWENTY YEARS OF ITS EXISTENCE. By Clemens Herschel. Pamphlet. 6 x 9 inches. 48 pp. Published by Builders Iron Foundry, Providence, R. I.

While in a sense a trade publication, this little paper is so interesting as an historical review of the invention of this important hydraulic instrument, of its registers, and of the uses to which it has been put, that it well deserves mention in this place.

THE DISINFECTION OF SEWAGE EFFLUENTS FOR THE PROTECTION OF PUBLIC WATER SUPPLIES. By Karl F. Kellerman, R. Winthrop Pratt, and A. Elliott Kimberley. United States Department of Agriculture, Bureau of Plant Industry. Bulletin No. 115. Washington: Government Printing Office. 1907.. Pamphlet. 6 x 9 inches. 47 pp.

A report of many tests of disinfection of sewage, at several places in Ohio, by the use of calcium hypochlorite, copper sulphate, and chlorin.